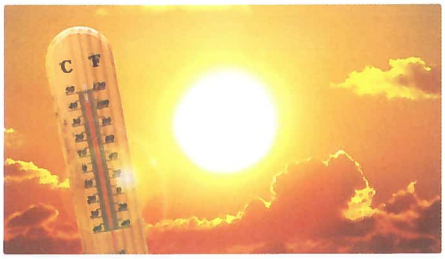
CONTENTS

UNIT 4 Thermochemistry

Chapter One Heat Content.

Lesson 1 — From: Energy. Until: Before heat content.

Lesson 2 — From: Heat content. Until: The end of the chapter.



Chapter Two Forms of Changes in Heat Content.

Lesson 1 — From: Heat changes accompanying physical and chemical changes. Until: Before heat changes accompanying chemical changes.

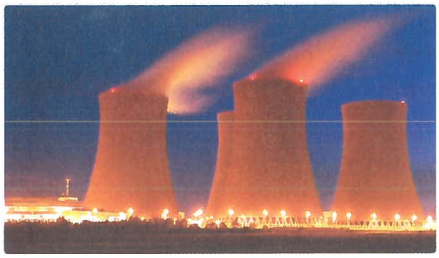
Lesson 2 — From: Heat changes accompanying chemical changes. Until: The end of the chapter.

UNIT 5 Nuclear Chemistry

Chapter One Nucleus and Elementary Particles.

Lesson 1 — From: Atom components. Until: Before strong nuclear forces.

Lesson 2 — From: Strong nuclear forces. Until: The end of the chapter.



Chapter Two Radioactivity and Nuclear Reactions.

Lesson 1 — From: Radioactivity and nuclear reactions. Until: Before nuclear transformation.

Lesson 2 — From: Nuclear transformation. Until: The end of the chapter.

- Exam model about the unit.
- 10 Open Book Exam models.

UNIT 4

Thermochemistry

Chapter One — Heat Content.

Lesson 1
From: Energy.
Until: Before heat content.

Lesson 2
From: Heat content.
Until: The end of the chapter.

General exercises on the unit

Chapter Two — Forms of Changes in Heat Content.

Lesson 1
From: Heat changes accompanying physical and chemical changes.
Until: Before heat changes accompanying chemical changes.

Lesson 2
From: Heat changes accompanying chemical changes.
Until: The end of the chapter.

Exam model about the unit

General objectives of unit four

By the end of this unit, the student will be able to :

- Identify the thermochemical equation.
- Identify the exothermic and endothermic reactions.
- Distinguish between the system and the surrounding.
- Compare between the types of different systems (opened - closed - isolated).
- Know the first law of thermodynamics.
- Infer that temperature is the measurement of the average kinetic energies of the system's particles.
- Clarify the relationship between the system energy and its particle movement.
- Identify the molar enthalpy (heat content).
- Apply the relationship that connects specific heat, heat capacity and heat change.
- Calculate the absorbed energy or released energy of the system.
- Achieve Hess's law for the constant heat summation.

Unit 4

Chapter One

Lesson 1

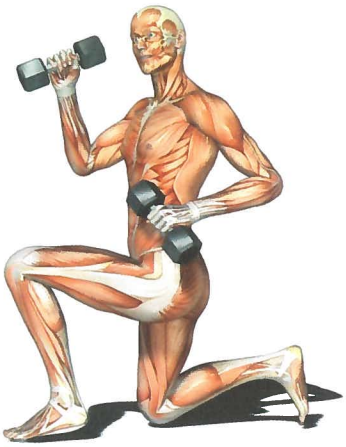
From Energy

Until Before heat content

Energy

★ Energy is very important in our life, where :

We can't carry out different activities (mental or muscular) without the produced energy from burning sugar inside our bodies.



Performing muscular activities requires energy

Law of conservation of energy

- **There are various forms of energy like :**
  - Chemical energy.
  - Heat energy.
  - Light energy.
  - Electrical energy.
  - Kinetic energy.

- In spite of this classification of energy into different forms, there is a relationship between all these forms, as energy can be converted from one form to another, this leads us to **the law of conservation of energy,** which states that the energy in any physical or chemical change can be neither created nor destroyed, but it is transformed from one form to another.

Thermochemistry

- **Thermodynamics** is the science that deals with the study of energy and how it transfers.
- **Thermochemistry** is the science which is concerned with the heat changes that accompanying the chemical changes (reactions) and the physical changes.

* The combination of hydrogen and oxygen gases to form water represents a chemical change (reaction).
* Dissolving ammonium nitrate salt in water represents a physical change.

* Most of the physical changes and the chemical reactions are accompanied by changing in energy.

☆ **Before studying how we can calculate the heat changes accompanying the chemical and physical changes, we have to know the following basic concepts :**

1. **System and surrounding.**
2. **First law of thermodynamics.**
3. **Heat and temperature.**
4. **Specific heat.**

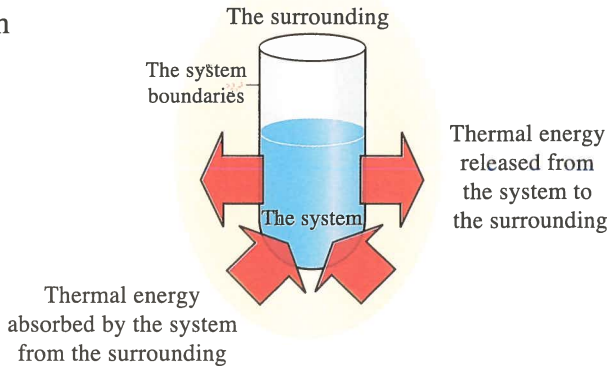
1 System and surrounding

- **System** is the part of the universe (or the substance) chosen for study, in which physical change or chemical reaction occurs.
- **Surrounding** is the part outside the system that exchanges energy with the system in the form of heat or work or both.
- **The chemical reaction can be expressed as a system as follows :**

The system	The system boundary	The surrounding
expresses	expresses	expresses
The reactants and products (The reaction medium)	The wall of container (a flask or a test tube) in which the reaction occurs	The medium surrounding the reaction container (The laboratory)

The relation between chemical reactions and energy

- The chemical reactions are accompanied with changes in energy (releasing or absorbing), this energy exchange occurs between the reaction medium (the system) and its surrounding.

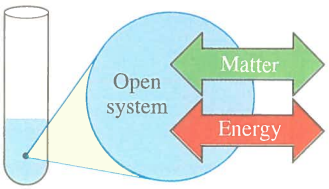


System and surrounding

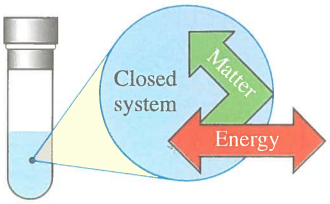
Types of systems

• **Systems are classified** according to their ability to exchange energy or matter with the surrounding **into :**

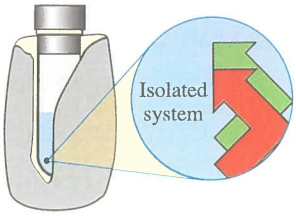
Open system
which is the system that freely exchanges matter and energy with its surrounding



Closed system
which is the system that exchanges energy (but not matter) with its surrounding in the form of heat or work



Isolated system
which is the system that exchanges neither energy nor matter with its surrounding.
i.e. the system doesn't interact with its surrounding



Example

The following figures represent three different systems, **Classify them with explanation.**

Solution

Figure	Type of the system	Explanation
(A)	Closed system	Because it allows the exchange of energy (heat) with the surrounding only
(B)	Isolated system	Because it doesn't allow the exchange of either energy or matter with the surrounding
(C)	Open system	Because it allows the exchange of energy and matter with the surrounding

Note

The medical thermometer is a closed system,
as it allows the exchange of energy only with the surrounding in the form of heat

2 First law of thermodynamics

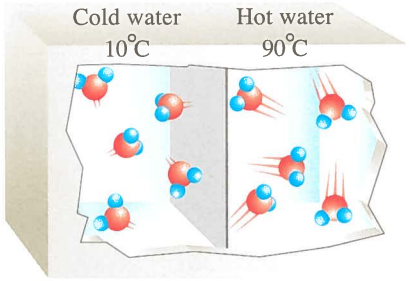
- When the system loses an amount of energy, the surrounding acquires it, and vice versa, So : Any change in the system's energy ΔE_{system} is accompanied by a change in the surrounding energy $\Delta E_{surrounding}$ by a similar value, but with an opposite sign, so that the total energy remains constant.

$$\Delta E_{system} = - \Delta E_{surrounding}$$

- **First law of thermodynamics includes the study of the energy exchange in the isolated systems, First law of thermodynamics** states that the total energy of an isolated system is constant even if the system is changed from one state to another.

3 Heat and temperature

- **Heat** is a form of energy, the flow of heat from one position to another depends on **the difference in temperature** between them.
- **Temperature** is the measurement of the average kinetic energy of matter molecules and it is an indication for the hotness and coldness of an object.
- The atoms or molecules of substances are in **a continuous motion (vibration),** but they differ in their speed in the same substance, so it is preferred to express the speed of molecules by the expression **"the average speed of molecules"**.
- When the system absorbs heat energy, the average speed of its molecules increases.
- This increases the kinetic energy of the molecules and leads to the rise of the temperature of the system and vice versa (direct relationship).



The kinetic energy of water molecules increases by increasing the quantity of heat that they absorb

There are two units for measuring the quantity of heat lost or gained by the system :

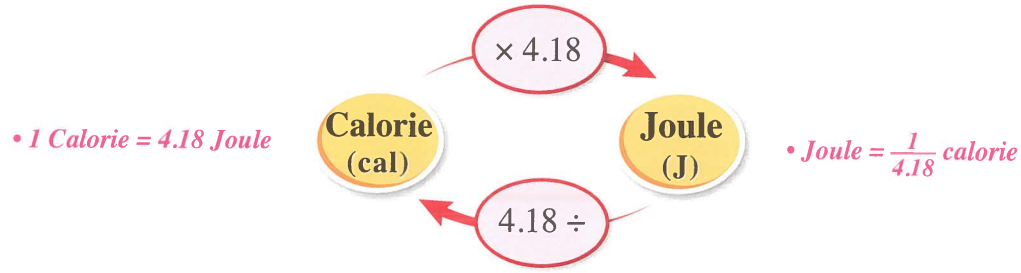
Calorie (cal)

Calorie is the quantity of heat needed to raise the temperature of 1 g of pure water by 1°C (15°C : 16°C)

Joule (J)

Joule is the quantity of heat needed to raise the temperature of 1 g of pure water by $\frac{1}{4.18}$ °C

The relationship between calorie and joule



Conversions of the units of the quantity of heat

4 Specific heat (c)

- **Specific heat** is the quantity of heat required to raise the temperature of one gram (1g) of the substance by one degree Celsius (1°C).

- **The unit used in measuring specific heat is J/g.°C**

What is meant by

The specific heat of copper is 0.385 J/g.°C ?
This means that the quantity of heat required to raise the temperature of 1 g of copper by 1°C equals 0.385 J

- **The following table shows the values of the specific heat of some substances :**

The substance	Copper	Iron	Carbon	Aluminum	Water vapor	Liquid water
Specific heat (J/g.°C)	0.385	0.448	0.711	0.9	2.01	4.18

- **Consequently, it is concluded that :**
  - Specific heat is **a characteristic property** for the substance, **because** specific heat is a constant value for the substance, but it differs from one substance to another and also it depends on the physical state of the substance.
  - Specific heat of water is **higher than** that of the other substances, **because** the quantity of heat required to raise the temperature of 1 g of water by 1°C is higher than that of the other substances.
  - The specific heat of the same substance **differs according to** its physical state, as can be noticed in case of water vapour and liquid water.

- The substance which requires the absorption of large quantity of heat for its temperature to be raised, its specific heat is high, and raising or decreasing the temperature of this substance takes long time, and vice versa.

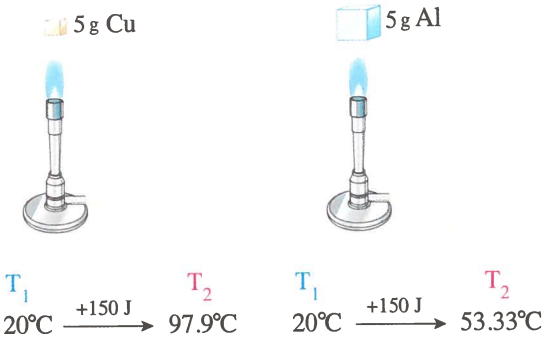
Application **In very cold countries, farmers sprinkle water over fruit trees.**

Because of the high specific heat of water, thus it protects fruits from freezing.

What would happen

When two equal masses of copper (its specific heat is 0.385 J/g.°C) and aluminum (its specific heat is 0.9 J/g.°C), both have the same initial temperature, are heated using the same source of heat for the same period of time ? **Give reason.**

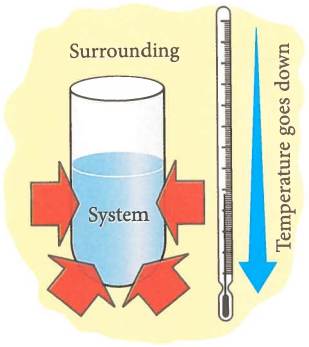
The temperature of copper rises more than that of aluminum, because the specific heat of copper is less than that of aluminum.



Calculation of the quantity of heat

- **The processes which include heat change are either :**

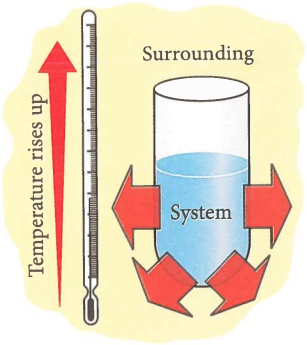
Endothermic processes



$T_{sur} > T_{sys}$

System gains thermal energy

Exothermic processes



$T_{sys} > T_{sur}$

System loses thermal energy

In which heat transfers

From the surrounding to the system, which leads to **dropping of** the temperature of **the surrounding (T_{sur})** and **rising of** the temperature of **the system (T_{sys})**, until both temperatures become equal

$T_{sur} = T_{sys}$

From the system to the surrounding, which leads to **rising of** the temperature of **the surrounding (T_{sur})** and **dropping of** the temperature of **the system (T_{sys})**, until both temperatures become equal

$T_{sys} = T_{sur}$

The quantity of heat (absorbed or released) in a certain system is directly proportional to the amount of the change in the temperature

* **The quantity of heat needed to raise or decrease the temperature of the system or the surrounding can be calculated by the following relation :**

Quantity of heat released or gained (q) under constant pressure (P) | Mass | Specific heat | Change in temperature $\Delta T = T_2 - T_1$

$$q_p = m \quad c \quad \Delta T$$

(J) (g) (J/g.°C) (°C)

- From the previous relation we can calculate each of the following :

Specific heat

$$c = \frac{q_p}{m \Delta T}$$

Initial and final temperatures (the change in temperature)

$$\Delta T = \frac{q_p}{m c}$$

$$T_{1(\text{Initial temp.})} = T_2 - \Delta T$$

$$T_{2\,(\text{Final temp.})} = \Delta T + T_1$$

Mass of the substance

$$m = \frac{q_p}{c \Delta T}$$

Examples

1 **Calculate the quantity of heat (expressed in Joule)** required to raise the temperature of 100 g of water by 21.5°C

Solution

$q_p = m c \Delta T$

$q_p = 100 \times 4.18 \times 21.5 = 8987$ J

2 **Calculate the quantity of heat (by J and cal)** required to raise the temperature of a piece of iron whose mass is 1.3 g from 25°C to 46°C, **where** the specific heat of iron is 0.448 J/g.°C

Solution

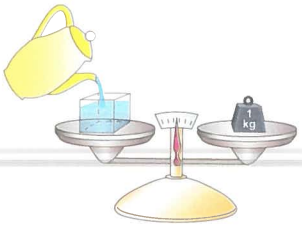
$\Delta T = T_2 - T_1 = 46 - 25 = 21$°C

$q_p = m c \Delta T = 1.3 \times 0.448 \times 21 = 12.23$ J

$q_{p(cal)} = \frac{12.23}{4.18} = 2.926$ cal

Convert the quantity of heat from (J ⟶ cal) by dividing over 4.18

* **In dilute solutions :**
  - The specific heat of the solution is equal to the specific heat of water (4.18 J/g.°C).
  - Mass of 1 mL of dil. solution = 1 g (as water density equals 1 g/cm^3).



The mass of 1 L (1000 mL) of water equals 1 kg (1000 g)

3 **Calculate the quantity of heat** absorbed as a result of dissolving 1 mol of ammonium nitrate in a certain amount of water to form 100 mL of solution, **where** the temperature drops from 25°C to 17°C

Solution

$q_p = m c \Delta T$

$= 100 \times 4.18 \times (17 - 25)$

$= -3344$ J

The negative sign of the value of q_p indicates that a quantity of heat equals 3344 J is lost by the surrounding and gained by the system

4 **Calculate the specific heat** of an unknown substance whose mass is 155 g and its temperature is raised from 25°C to 40°C when it absorbs an amount of heat equals 5700 J

Solution

$$c = \frac{q_p}{m \Delta T} = \frac{5700}{155 \times (40 - 25)} = 2.45 \text{ J/g.°C}$$

5 **Calculate the specific heat of water in J/kg.°C**

Solution

$$\because c = 4.18 \frac{J}{g.°C} = \frac{4.18}{10^{-3}} \frac{J}{kg.°C}$$

$\therefore$ c (J/kg.°C) $= 4.18 \times 1000 =$ 4180 J/kg.°C

6 6 kg sample of sand with initial temperature 20°C gained a quantity of heat equals 65000 J, **Calculate the final temperature of the sample,** knowing that the specific heat of the sand is 840 J/kg.°C

Solution

$$\because \Delta T = \frac{q_p}{m c} = \frac{65000}{6 \times 840} = 12.897°C$$

$\therefore T_2 = \Delta T + T_1 = 12.897 + 20 =$ 32.897°C

If the mass is in (kg) and the specific heat is in (J/kg.°C), then their values can be used in the calculations without conversions

7 **Calculate the temperature of a mixture formed** of 100 g of water its temperature is 25°C and 200 g of water its temperature is 37°C, assuming that the lost quantity of heat equals the absorbed quantity of heat.

Solution

$q_p = m c \Delta T$

$q_{(absorbed)} = 100 \times 4.18 \times (T - 25)$, $q_{(lost)} = 200 \times 4.18 \times (T - 37)$

$\because q_{(absorbed)} = -q_{(lost)}$

$\therefore [100 \times 4.18 \times (T - 25)] = -[200 \times 4.18 \times (T - 37)]$

$[418 T - 10450] = -[836 T - 30932]$

$418 T + 836 T = 10450 + 30932$

$1254 T = 41382$

$\therefore T =$ 33°C

The Calorimeter

Its components:

- Isolated container (to prevent any exchange of energy or matter between the system and the surrounding).
- Stirrer.
- The reactants (represent the isolated system).
- Thermometer.

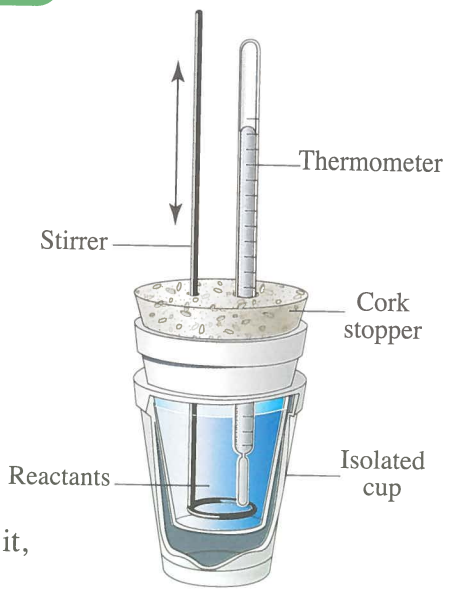
Usage :

- It is used to determine the change in temperature of the chemical reactions ΔT by knowing each of :

  The initial temperature T_1 and the final temperature T_2

Idea of working :

- It works as an isolated system for the substances inside it, as it prevents losing or gaining any quantity of heat or substance with its surrounding.



The calorimeter
"coffee - cup calorimeter"

☆ **There are other types of calorimeters, such as the bomb calorimeter.**

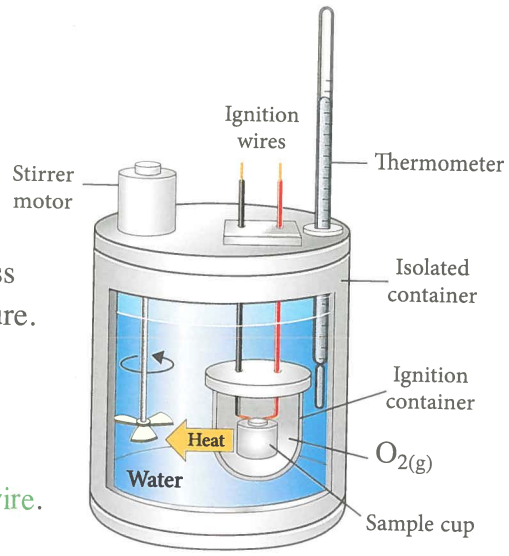
The bomb calorimeter

Usage :

- Used to measure the heat of combustion of some substances.

Procedure :

- A known amount of substance is burned in an excess amount of oxygen under normal atmospheric pressure.
- It is placed in an isolated steel container called the steel bomb which is surrounded by a definite amount of the heat exchange liquid (almost water).
- The substance is ignited by using an electric ignition wire.
- The amount of heat transfers from the burnt substance (the system) to the heat exchange liquid (the surrounding), so its temperature rises by this amount of heat.
- The combustion temperature is determined by measuring the change in temperature of the heat exchange liquid (water).



The bomb calorimeter

Note

Water is used in the calorimeter as a heat exchange liquid, due to its high specific heat which allows it to absorb or lose a large amount of heat energy

Questions ?

UNIT 4 — Chapter One — Lesson 1

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Choose the correct answer :

(1) Most of the physical changes and chemical reactions are accompanied with a change in .....

a. color. b. mass. c. energy. d. density.

(2) In the chemical reaction, the beaker in which the reaction occurs represents .....

a. the system. b. the system boundary. c. the surrounding.

(3) The quantity of heat required to raise the temperature of 1 g of water by $\frac{1}{4.18}$ °C is called .....

a. Joule. b. calorie. c. specific heat. d. heat content.

(4) The measuring unit of the specific heat is .....

a. J/g.°C b. J/°K c. J/mol d. J

(5) Which one of the following substances has higher specific heat ? .....

a. 1 g of water. b. 1 g of iron. c. 1 g of aluminum. d. 1 g of mercury.

(6) The specific heat for a metallic ball depends on .....

a. its type of matter. b. its mass.

c. its volume. d. its surface area.

2 What is meant by that the specific heat of aluminum = 0.9 J/g.°C ?

3 Give reasons for :

(1) The total energy of any isolated system is constant.

(2) When a liquid loses an amount of heat its temperature decreases.

(3) The calorimeter is used in experiments of thermodynamics.

(4) Water is used in the bomb calorimeter.

4 What happens when.. ?

(1) Increasing the mass to double, with respect to "specific heat".

(2) 1 g of substance absorbed a quantity of heat equals its specific heat.

5 You have three samples of different metals shown in the following table with the same initial temperature, and the mass of each sample is 70 g :

Metal	Specific heat (J/g.°C)
Platinum	0.133
Titanium	0.528
Zinc	0.388

Which of these samples its temperature increases first when they are all heated with the same thermal source ? Why ?

Steady

Open book questions

Answered

Multiple choice questions

1 Which of the following is an application of law of conservation of energy ? .....

(a) The total energy of an isolated system which contains ice remains the same even when the ice is turned to water.

(b) Hydrogen gas and oxygen gas react together to form water with releasing thermal energy.

(c) In photosynthesis, light energy converts into chemical energy.

(d) Reaction of magnesium with oxygen is accompanied by absorbing thermal energy.

2 Which of the following statements represents a closed system ? .....

(a) The incoming mass = the outgoing mass from the system.

(b) Matter does not transfer either to or from the system.

(c) Incoming matter in the system might be more or less than the outgoing matter.

(d) It does not exchange either heat or work with its surrounding.

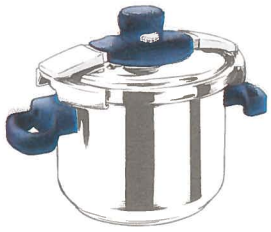
3 What is the system which includes a constant mass of matter ? .....

(a) Equilibrium system.
(b) Open system.
(c) Closed system.
(d) Thermally equilibrium system.

4 Car fuel tank is an example for the .....

(a) equilibrium systems
(b) isolated systems
(c) closed systems
(d) open systems

5 The opposite figure shows a pressure cooker, it does not allow the liquids found inside it to escape during cooking, this is why the pressure cooker is considered as a(an) .....



(a) closed system.
(b) open system.
(c) isolated system.
(d) equilibrium system.

6 Which of the following statements is correct ? .....

(a) The concept of temperature is the same concept of heat.

(b) The concept of temperature is the same concept of kinetic energy of matter molecules.

(c) Heat is a characteristic property of the substance.

(d) The concept of temperature represents the internal energy of matter molecules.

7 The average kinetic energy of H_2O molecules decreases by the conversion of a certain mass of .....

(a) liquid water its temperature is 64°C to liquid water its temperature is 27°C

(b) liquid water its temperature is 100°C to water vapour its temperature is 100°C

(c) ice its temperature is –73°C to ice its temperature is –36°C

(d) ice its temperature is 0°C to water its temperature is 0°C

8 The quantity of energy which is equivalent to 50 kJ is .....

(a) 0.05 J

(b) 500 J

(c) 5×10^3 J

(d) 5×10^4 J

Questions marked by this mark are for the superiors and their ideas are explained in the answers

9 Kilocalorie is one of energy units which equals .....

(a) 418 J

(b) 4.18 J

(c) 4180 J

(d) 41.8 kJ

10 Specific heat of water is higher than that of mercury .. Which of the following statements does not agree with the previous information ? .....

(a) The quantity of heat required to raise the temperature of 10 g of water by 15°C is higher than that required to raise the temperature of the same mass of mercury by the same degrees.

(b) The quantity of heat released by lowering the temperature of 20 g of water by 10°C is higher than that released by lowering the temperature of the same mass of mercury by the same degrees.

(c) The quantity of heat released by lowering the temperature of 100 g of water from 80°C to 20°C equals the quantity of heat released by lowering the temperature of the same mass of mercury from 80°C to 20°C

(d) By heating two equal masses of water and mercury, both have the same initial temperature, with the same quantity of heat, the final temperature of mercury will be higher than that of water.

11 If the temperature of a substance is doubled as well as its mass, its specific heat will be .....

(a) decreased to quarter.

(b) constant.

(c) increased to double.

(d) increased to four times.

12 If two bodies that have the same mass, both gain the same quantity of heat, and the rise in the temperature of the second body is double that of the first, therefore the specific heat of the second body is .....

(a) equal to the first one.
(b) double the first one.
(c) half the first one.
(d) quarter the first one.

13 All the following can be identified by knowing the specific heat of metals, except .....

(a) the quantity of heat needed to raise the temperature of 10 g of a metal by 10°C
(b) the quantity of heat released by cooling 10 g of a metal from 100°C to 25°C
(c) the internal energy of the metal.
(d) the gram atomic mass of the metal.

14 What is the quantity of heat which is released by cooling 50 g of water from 20°C to 10°C ? .....

(a) 5×10^2 J
(b) 1.67×10^5 J
(c) 2.09×10^3 J
(d) 1.13×10^6 J

15 A sample of water its mass equals 100 g, its initial temperature is 22°C, this sample acquired a quantity of heat which equals 8360 J .. What is the final temperature of the sample ? .....

(a) 18.3°C
(b) 20°C
(c) 25.7°C
(d) 42°C

16 What is the temperature of the mixture formed of 100 g of water with temperature 15°C and 250 g of water with temperature 50°C in a supposedly isolated system ? .....

(a) 31.4°C
(b) 40°C
(c) 44°C
(d) 50°C

17 The bomb calorimeter is used to measure the heat of combustion of some substances .....

(a) under normal atmospheric pressure.
(b) at 25°C
(c) at 100°C
(d) under high pressure.

Essay questions

18 The opposite figure represents a closed system..

How can you convert this system to :

(1) An open system.

(2) An isolated system.

19 If you know that the specific heat of 1 g of iron equals 0.448 J/g.°C
What is the specific heat of 10 g of iron ? **"With explanation".**

20 **What is meant by that** raising the temperature of 1 kg of a substance by 1°C requires a quantity of heat equals 700 J ?

21 **What can be concluded from the following values ... ?**
- Specific heat of water = 4.18 J/g.°C
- Specific heat of water vapor = 2.01 J/g.°C

22 When two equal masses of aluminum and water (with the same initial temperature) acquire the same quantity of heat ..
Why would the temperature of aluminum **be higher than** that of water ?

23 "In a trip to one of the beaches, students observed that there is a difference in temperature between water and sand at noon",
Which of them has higher temperature ? "Giving reason".
(1) At noon. **(2)** At midnight.

24 **What does happen when ...**
(1) Two equal masses of water and iron with the same initial temperature are heated, each individually, for the same period of time using the same source of heat ?
(2) A combustion reaction is carried out inside a calorimeter "relating to water which is found inside it" ?

25 **Can** a dilute solution be expressed by the indication of its volume ? **Explain.**

26 **Calculate the quantity of heat** required to raise the temperature of 1500 g of oil – before using it in the frying process – from 20°C to 180°C,
knowing that the specific heat of the used oil is 1970 J/kg.°C

27 **Calculate the quantity of heat** needed to raise the temperature of 500 g of ethanol from 20.2°C to 44.1°C, knowing that the specific heat of ethanol equals 2.42 J/g.°C

28 **Calculate the quantity of heat** absorbed by 40 g of water to raise its temperature by 20°C, **knowing that** the specific heat of water is 4.18 J/g.°C, if the temperature of 30 g of oil rises by 70°C when absorbing the same amount of heat .. **What is the specific heat of oil ?**

29 Two equal masses 6 kg of sand and water, their temperature is 20°C, they absorbed 65000 J of heat in the same period of time .. **What is the final temperature of each one ?**
What do you conclude ? (Where, c_{water} = 4180 J/kg.°C, c_{sand} = 840 J/kg.°C).

New types of questions ?

Answered

Choosing two out of five choices questions :

1 **What are the two choices which represent the first law of thermodynamics ?** .....

(a) Work (W) exerted by the system has a negative value.

(b) Work (W) exerted on the system has a negative value.

(c) Quantity of heat (q) lost and transferred from the system to the surrounding has a positive value.

(d) Quantity of heat (q) added to the system has a positive value.

(e) The thermal change which occurs in the system equals that which occurs in the surrounding.

2 **In the opposite table which shows the values of the specific heat of five different metals with the same initial temperature..**
What are the two metals whose temperatures rise to higher extent when 1 g of each of them is provided by the same amount of heat for the same period of time ? .....

Metal	Specific heat (J/g.°C)
Al	0.9
Au	0.129
Cu	0.385
Cr	0.499
Hg	0.139

(a) Al (b) Au (c) Cu

(d) Cr (e) Hg

3 **What are the two substances whose heat of combustion can be calculated by using a calorimeter ?** .....

(a) Water. (b) Carbon dioxide.

(c) Ethyl alcohol. (d) Nitrogen dioxide.

(e) Methane.

The sketch questions :

4 **Choose from the following list what is suitable for each of the kettle shown in figure (1), and the pressure cooker shown in figure (2).**

An isolated system	Its temperature does not change by time	Its mass increases by time
A closed system	Does not allow the exchange of energy	Its mass decreases by time

Figure (1)

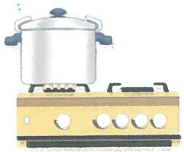


Figure (2)

- The kettle : .....
- The pressure cooker : .....

Unit 4

Chapter One

Lesson 2

From Heat content

Until The end of the chapter

Heat content

- Each substance stores an amount of energy inside it. This amount of energy is called the internal energy.
- This amount of energy is the summation of three types of energy, **which are :**

1 The stored energy in the atom

It is represented in the energy of electrons in the energy levels and it is the summation of kinetic energy and potential energy of the electron in its energy level.

2 The stored energy in the molecule

It is represented in the energy that is found in the chemical bonds between atoms (ions) with each other, whether these bonds are ionic bonds or covalent bonds.

3 The stored energy between molecules

It is represented in the intermolecular forces like :

- **Van der Waals forces :** It is considered as a potential energy.
- **Hydrogen bonds :** These bonds depend on the nature of molecules and their polarity.

☆ **The sum of these energies in one mole of a substance is called the molar enthalpy (H) or the heat content of the substance, it is measured in kJ/mol**

What is meant by

The molar enthalpy of NO_2 gas equals 33.58 kJ/mol ?

This means that the sum of the stored energies in 1 mol of NO_2 gas equals 33.58 kJ

* **The heat content differs from one substance to another,** because molecules of different substances differ in the number and the type of atoms (or the ions of the formula unit), as well as the number and the type of bonds between their atoms (or ions).

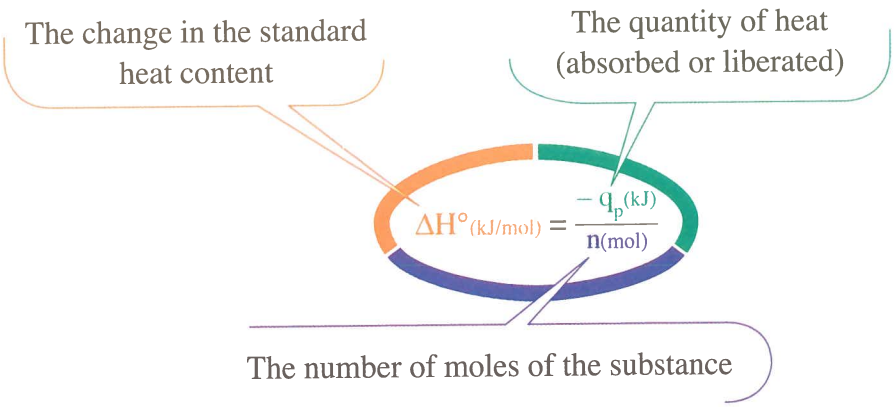
* It is not possible to measure the molar enthalpy (heat content) for a certain substance, but we can measure **the change that occurs in the heat content ΔH** during the different changes that occur in the substance during the chemical reactions.

The change in heat content = Sum of heat contents of the products – Sum of heat contents of the reactants

$$\Delta H = H_{products} - H_{reactants}$$

- The change in heat content for different chemical reactions which are carried out under the same standard conditions is called **the change in standard heat content ΔH°** **which is determined from the relation :**

The standard conditions are :
- Pressure that equals 1 atm (normal atmospheric pressure).
- Temperature = 25°C (room temperature).
- Concentration = 1 M (molar concentration).



- **Considering the signs illustrated in the following table :**

	Exothermic processes	Endothermic processes
Change in temperatures (ΔT)	With a positive sign	With a negative sign
Thermal energy accompanying the system (Quantity of heat) (q_p)	Released energy with a positive sign	Absorbed energy with a negative sign
Change in heat content (the enthalpy) (ΔH)	With a negative sign	With a positive sign

Examples

1 **Calculate the quantity of heat released** from burning 5.76 g of methane gas CH_4 in an excess amount of oxygen gas at constant pressure, **according to the reaction :**

$$CH_{4(g)} + 2O_{2(g)} \xrightarrow{\Delta} CO_{2(g)} + 2H_2O_{(v)} \qquad \Delta H° = -890 \text{ kJ/mol} \qquad [C = 12 , H = 1]$$

Solution

Molar mass of $CH_4 = 12 + (4 \times 1) = 16$ g/mol

$$\text{Number of moles (n)} = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{5.76}{16} = 0.36 \text{ mol}$$

$$\because \Delta H° = \frac{-q_p}{n}$$

$\therefore$ The quantity of released heat $(q_p) = -(\Delta H° \times n)$

$= -(-890 \times 0.36) = +320.4$ kJ

2 **Calculate the amount of heat absorbed** by the decomposition of 85 g of ammonia gas, **according to the following equation :**

$$NH_{3(g)} \longrightarrow \frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \qquad \Delta H° = +46 \text{ kJ/mol} \qquad [N = 14 , H = 1]$$

Solution

Molar mass of $NH_3 = 14 + (3 \times 1) = 17$ g/mol

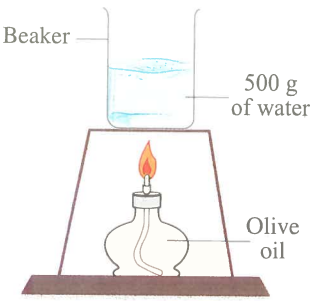
$$\text{Number of moles (n)} = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{85}{17} = 5 \text{ mol}$$

$$\because \Delta H° = \frac{-q_p}{n}$$

$\therefore q_p = -\Delta H° \times n = -(+46 \times 5) = -230$ kJ

3 **The opposite figure represents** the process of heating 500 g of water by the thermal energy resulting from burning olive oil, **using the following table :**

Initial temperature of water	21°C
ΔH of burning olive oil	– 41 kJ/g
The amount of lost heat	28 kJ



Calculate the final temperature of water after the complete burning of 2.97 g of olive oil.

Solution

Amount of heat released from burning 2.97 g of olive oil

$q_{p(\text{olive oil})} = -(\Delta H \times m)$

$= -(-41 \times 2.97) = 121.77$ kJ

Amount of heat required to heat 500 g of water

= Released heat – Lost heat

If the value of ΔH is estimated in the unit (kJ/g), then the mass (m) will be used in the calculations instead of number of moles (n)

$\therefore q_{p(water)} = q_{p(olive\ oil)} - q_{p(lost)}$

$= 121.77 - 28 = 93.77\ kJ = 93770\ J$

$\because q_{p(water)} = m\,c\,\Delta T$ $\quad\quad$ $\therefore \Delta T = \frac{q_p}{m\,c} = \frac{93770}{500 \times 4.18} = 44.87°C$

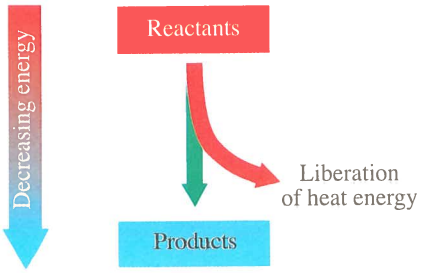
$\therefore T_2 = \Delta T + T_1 = 44.87 + 21 = 65.87°C$

Exothermic and Endothermic reactions

According to the heat changes accompanying the chemical reactions, **we can classify the chemical reactions into :**

Exothermic reactions

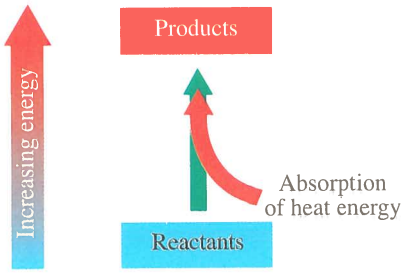
Exothermic reactions the reactions that produce heat to the surrounding causing an increase in its temperature.



Exothermic reactions

Endothermic reactions

Endothermic reactions the reactions that absorb heat from the surrounding causing a decrease in its temperature.



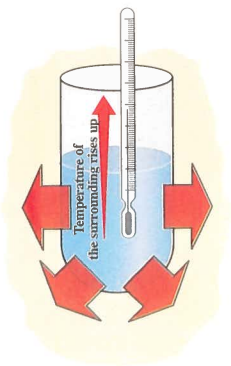
Endothermic reactions

The path of the thermal energy

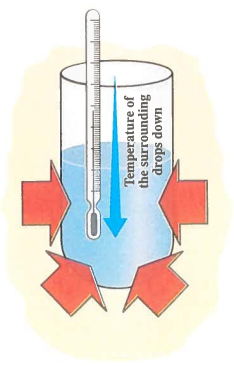
* The heat transfers from the system to the surrounding, **which leads to :**
  - Dropping of the temperature of the system.
  - Rising of the temperature of the surrounding.

* The heat transfers from the surrounding to the system, **which leads to :**
  - Rising of the temperature of the system.
  - Dropping of the temperature of the surrounding.

‹‹The surrounding means the solvent and the air which surrounds the reaction container››



Exothermic reaction



Endothermic reaction

The change in the standard heat content ΔH°

* ΔH° of the exothermic reactions has **a negative sign**, **because** the heat content (the molar enthalpy) of the products **is lower than** that of the reactants.

$\because H_{prod} < H_{react}$

$\because \Delta H° = H_{prod} - H_{react}$

$\therefore \Delta H° < 0$

* ΔH° of the endothermic reactions has **a positive sign**, **because** the heat content (the molar enthalpy) of the products **is higher than** that of the reactants.

$\because H_{prod} > H_{react}$

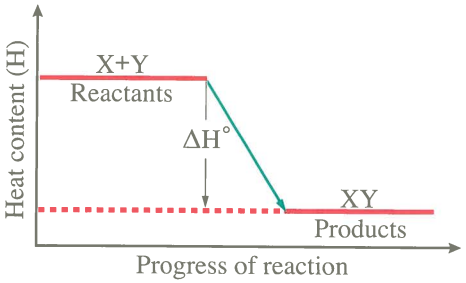
$\because \Delta H° = H_{prod} - H_{react}$

$\therefore \Delta H° > 0$

General diagram of the reaction

$X + Y \longrightarrow XY$ ΔH° (–)

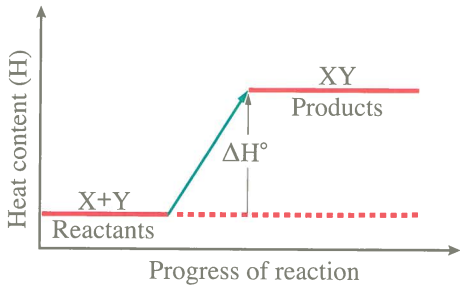
Reactants Products



Energy diagram of exothermic reactions

$X + Y \longrightarrow XY$ ΔH° (+)

Reactants Products



Energy diagram of endothermic reactions

Application

Reaction between hydrogen and oxygen gases to form water.

$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(\ell)} + 285.8\ kJ/mol$

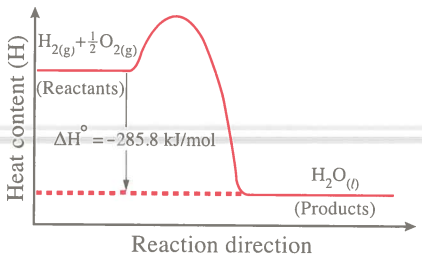
Decomposition of magnesium carbonate to magnesium oxide and carbon dioxide.

$MgCO_{3(s)} + 117.3\ kJ/mol \longrightarrow MgO_{(s)} + CO_{2(g)}\uparrow$

The energy diagram of the reaction

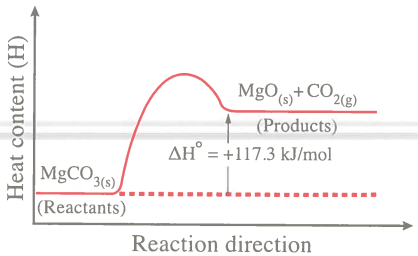
$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(\ell)}$

$\Delta H° = -285.8\ kJ/mol$



$MgCO_{3(s)} \longrightarrow MgO_{(s)} + CO_{2(g)}\uparrow$

$\Delta H° = +117.3\ kJ/mol$



Notes

1. **The exothermic reaction is accompanied with releasing an amount of heat, because** the sum of heat contents of the products is less than that of the reactants and according to the law of conservation of energy. The decrease in the heat content of products must be compensated by releasing an amount of energy.
2. **The endothermic reaction is accompanied with absorbing an amount of heat, because** the sum of heat contents of the reactants is less than that of the products and according to the law of conservation of energy. The decrease in the heat content of reactants must be compensated by absorbing an amount of energy.

Thermochemical equation

Thermochemical equation is a symbolic chemical equation that includes the change in heat content (molar enthalpy) accompanying the chemical reaction which is represented sometimes in the equation as one of the reactants or products.

★ **The thermochemical equation should have some conditions as shown in the following table :**

The conditions of thermochemical equation	Application
1 It must be **balanced**. If necessary, we can write **the coefficients** as fractions.	$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(\ell)}$ $\Delta H° = -285.8$ kJ/mol
2 **The physical state** of the reactants and the products must be written.	$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(v)}$ $\Delta H° = -242$ kJ/mol
3 Putting a positive or a negative sign beside ΔH : **+ve** ⇒ In case of absorbing heat. **(endothermic)** **–ve** ⇒ In case of liberating heat. **(exothermic)**	"The value of $\Delta H°$ of water changes by changing its physical state" $N_{2(g)} + 2H_{2(g)} \longrightarrow N_2H_{4(\ell)}$ $\Delta H° = +91$ kJ/mol $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(v)}$ $\Delta H° = -890$ kJ/mol
4 When **multiplying or dividing** the coefficients of the two sides of the equation with a certain numerical coefficient. The same operation must be carried out on ΔH	$H_2O_{(s)} \longrightarrow H_2O_{(\ell)}$ $\Delta H° = +6$ kJ/mol **Multiplying the equation × 2 :** $2H_2O_{(s)} \longrightarrow 2H_2O_{(\ell)}$ $\Delta H = 2 \times (+6) = +12$ kJ
5 When the process (the direction of the reaction) is **inversed**, the sign of the heat content ΔH is **inversed**.	$H_2O_{(s)} \longrightarrow H_2O_{(\ell)}$ $\Delta H° = +6$ kJ/mol $H_2O_{(\ell)} \longrightarrow H_2O_{(s)}$ $\Delta H° = -6$ kJ/mol

Notes

1. **We can write the coefficients of the balanced chemical equation as fractions, because** the coefficients represent the number of moles of the reactants and the products not the number of molecules or atoms.
2. **The physical state of the reactants and the products must be mentioned in the thermochemical equation, because** the heat content (molar enthalpy) changes with the change of the physical state of the substance.
3. **The value of $\Delta H°$ of the following reaction is positive :**

$$H_2O_{(s)} \longrightarrow H_2O_{(l)} \qquad \Delta H° = +6.03 \text{ kJ/mol}$$

because the melting of ice into liquid water requires thermal energy (heat) to break the hydrogen bonds between the molecules of the ice.

Example

Calculate the change in heat content (enthalpy change) resulting from the decomposition of 252 g of magnesium carbonate by heat under constant pressure according to the following equation :

$$MgCO_{3(s)} \xrightarrow{\Delta} MgO_{(s)} + CO_{2(g)} \qquad \Delta H° = +117.3 \text{ kJ/mol}$$

[Mg = 24 , C = 12 , O = 16]

Solution

Molar mass of $MgCO_3 = 24 + 12 + (3 \times 16) = 84$ g/mol

$$\text{Number of moles of } MgCO_3 = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{252}{84} = 3 \text{ mol}$$

$MgCO_{3(s)}$	$\longrightarrow$	ΔH
1 mol		+117.3 kJ
3 mol		? kJ

∴ The change in enthalpy (ΔH) produced from the thermal decomposition of 252 g (3 mol) of $MgCO_3 = 117.3 \times 3$

$= 351.9$ kJ

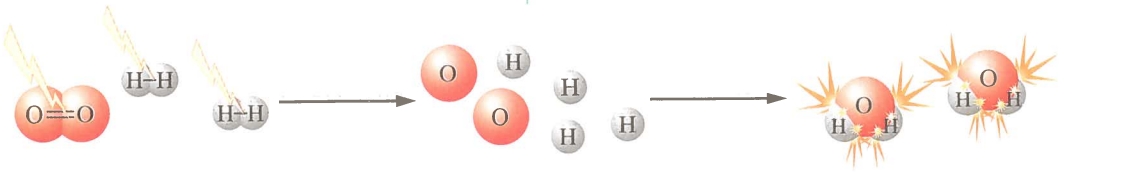
Bond Energy

* Chemical bonds store chemical energy in the form of potential energy.
* **Bond energy** is the amount of energy absorbed to break the bonds or released during the formation of bonds in one mole of the substance.

In the chemical reaction

Breaking down the bonds between the atoms of reactants

Formation of new bonds between the atoms of products



Breaking down of bonds needs absorbing energy

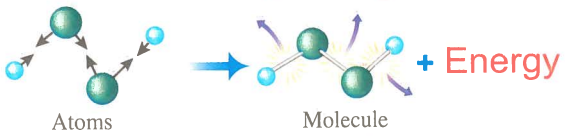
Formation of separated atoms

Formation of bonds is accompanied by releasing energy

- **The breaking of bonds is an endothermic process and needs absorbing an amount of energy from the surrounding, so its ΔH° has a positive sign.**

Breaking bonds is an endothermic process

- **The formation of bonds is an exothermic process and results in releasing an amount of energy to the surrounding, so its ΔH° has a negative sign.**



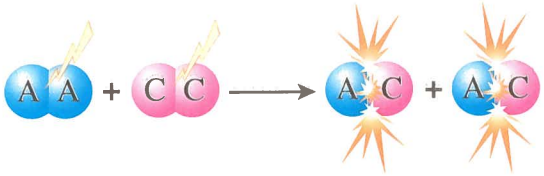
Formation of bonds is an exothermic process

- **The algebraic sum** of absorbed and released energies during the chemical reaction represents the change in heat content of this reaction ΔH

ΔH =	Absorbed energy during the breaking of bonds **(Positive sign)**	+	Released energy during the formation of bonds **(Negative sign)**

- From the previous, the type of the reaction can be determined, **where :**

Exothermic reactions



Breaking down bonds absorbs lower amount of energy

Formation of bonds releases larger amount of energy

The released energy during the formation of bonds in the molecules of the products is

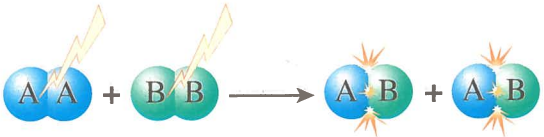
higher than

The absorbed energy during the breaking of bonds in the molecules of the reactants.

So,

The reaction will be exothermic and its ΔH° value will have a negative sign.

Endothermic reactions



Breaking down bonds absorbs larger amount of energy

Formation of bonds releases lower amount of energy

The absorbed energy during the breaking of bonds in the molecules of the reactants is

higher than

The released energy during the formation of bonds in the molecules of the products.

So,

The reaction will be endothermic and its ΔH° value will have a positive sign.

Note

The concept of average bond energy is used instead of the bond energy, because each bond energy differs according to the type of the compound and its physical state

- **The following table shows the average energy for some bonds :**

Bond	Average bond energy (kJ/mol)	Bond	Average bond energy (kJ/mol)
H – H	432	C – C	346
O – H	467	C = C	610
C – H	413	C ≡ C	835
N – H	389	C – O	358
O = O	498	C = O	803

What is meant by

The average bond energy of (C – C) equals 346 kJ/mol ?

This means that the absorbed (or released) energy during breaking (or formation) of this bond in one mole of substance in the standard conditions, equals 346 kJ

Examples

1 Assisted with the values of the average bond energies in the opposite table,

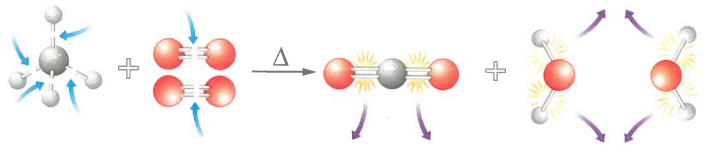
Calculate ΔH for the following reaction and determine if the reaction is exothermic or endothermic :

$CH_{4(g)} + 2O_{2(g)} \xrightarrow{\Delta} CO_{2(g)} + 2H_2O_{(v)}$

Bond	Average bond energy (kJ/mol)
C – H	413
O = O	498
C = O	803
O – H	467

Solution

Drawing for illustration only



Absorbing energy during breaking bonds *Releasing energy during formation of bonds*

- The absorbed energy during breaking the reactants bonds

  = [4(C – H) + 2(O = O)] = [4 × (413) + 2 × (498)] = +2648 kJ

- The released energy during the formation of bonds in the products

  = [2(C = O) + 2 × 2(O – H)] = [2 × (– 803) + (4 × – 467)] = – 3474 kJ

ΔH = Absorbed energy during the breaking of bonds of the reactants
+ Released energy during the formation of bonds of the products

= (+ 2648) + (– 3474)= – 826 kJ/mol

- The reaction is exothermic, because ΔH has a negative sign.

2 **Calculate ΔH of the following reaction :**

$N_{2(g)} + 2H_{2(g)} \longrightarrow H_2N - NH_{2(\ell)}$

Assisted by the values of average bond energies shown in the opposite table.

Then determine if the reaction is exothermic or endothermic, Why ?

Bond	Average bond energy (kJ/mol)
N ≡ N	946
H – H	432
N – N	163
N – H	389

Solution

* The absorbed energy during breaking bonds of reactants

$= [(N \equiv N) + 2(H - H)] = [946 + (2 \times 432)] = +1810$ kJ

* The released energy during the formation of bonds of products

$= [4(N - H) + (N - N)] = [(4 \times -389) + (-163)] = -1719$ kJ

ΔH = Absorbed energy during breaking the reactants bonds

+ Released energy during formation of the products bonds

$= (+1810) + (-1719) = +91$ kJ/mol

- This reaction is an endothermic reaction, because ΔH value has a positive sign, because the absorbed energy during breaking bonds of reactants > the released energy during the formation of bonds of products.

3 **Calculate the average bond energy of oxygen gas in the following reaction :**

$2H_2O_{(\ell)} \longrightarrow 2H_{2(g)} + O_{2(g)}$ $\Delta H = +506$ kJ

knowing that : (O – H) = 467 kJ/mol , (H – H) = 432 kJ/mol

Solution

$2(H - O - H) \longrightarrow 2(H - H) + (O = O)$

* The absorbed energy during breaking the reactants bonds

$= [2 \times 2(O - H)] = 4 \times 467 = +1868$ kJ

ΔH = Absorbed energy during breaking the reactants bonds

+ Released energy during formation of the products bonds

ΔH = (+ 1868) + The released energy during formation of the products bonds

$+ 506 = (+ 1868) - [2 (H - H) + (O = O)]$

$+ 506 = (+ 1868) - (2 \times 432) - (O = O)$

$\therefore (O = O) = +1868 - 864 - 506 = +498$ kJ/mol

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Choose the correct answer :

(1) The energy of the electron in any energy level equals .....

a. (potential energy ÷ kinetic energy) of each electron.

b. (potential energy – kinetic energy) of each electron.

c. (potential energy + kinetic energy) of each electron.

d. (potential energy × kinetic energy) of each electron.

(2) The standard conditions for the reaction are .....

a. pressure 1 atm, temperature 0°C

b. pressure 1 atm, temperature 25°C

c. pressure 1 atm, temperature 100°C

d. pressure 1 atm, temperature 273°C

(3) If the heat content of products is lower than that of reactants, thus the reaction .....

a. is endothermic.

b. is exothermic.

c. has ΔH value with a positive sign.

d. has ΔH value = zero

(4) Which of the following choices represents both the type of the process of the formation of the bonds, and the sign of its ΔH ? .....

Choices	a	b	c	d
Type of the process	Endothermic	Endothermic	Exothermic	Exothermic
ΔH sign	Negative	Positive	Negative	Positive

(5) In the reaction $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)} + 112\ kJ$, ΔH has .....

a. negative sign, because the reaction is endothermic.

b. positive sign, because the reaction is endothermic.

c. negative sign, because the reaction is exothermic.

d. positive sign, because the reaction is exothermic.

2 Give reasons :

(1) Molar enthalpy differs from a substance to another.

(2) The physical state of the reactants and the products must be written in the thermochemical equation.

(3) The endothermic reactions are accompanied with absorbing an amount of heat.

(4) The average bond energy is used instead of the bond energy.

3 What is meant by... ?

(1) The molar enthalpy of NO_2 gas equals 33.58 kJ/mol

(2) ΔH for a reaction equals –383.5 kJ/mol

(3) ΔH value of a certain reaction is positive.

(4) The average bond energy of (H – H) is 432 kJ/mol

Steady

Open book questions

Answered

Multiple choice questions

1 In the following reaction :

$CH_{4(g)} + 2O_{2(g)} \xrightarrow{\Delta} CO_{2(g)} + 2H_2O_{(v)}$ $\quad \Delta H° = -890$ kJ/mol

The heat released from combustion of 3 mol of methane is .....

(a) –2670 kJ (b) –890 kJ

(c) –296.6 kJ (d) +2670 kJ

Questions marked by this mark are for the superiors and their ideas are explained in the answers

2 In the following reaction :

$2Na_2O_{2(s)} + 2H_2O_{(l)} \longrightarrow 4NaOH_{(s)} + O_{2(g)}$ $\quad \Delta H = -126$ kJ

What is the quantity of heat released by producing 2 mol of NaOH ? .....

(a) +252 kJ (b) +63 kJ

(c) +3.9 kJ (d) +78 kJ

3 In the reaction : $2H_2O_{2(l)} \longrightarrow 2H_2O_{(l)} + O_{2(g)}$ $\quad \Delta H = -196$ kJ

What is the change in the enthalpy of the decomposition of 0.34 g of hydrogen peroxide H_2O_2 ? ..... [H = 1 , O = 16]

(a) –0.98 kJ (b) –1.96 kJ

(c) –196 kJ (d) –98 kJ

4 Sulphur burns according to the equation : [S = 32]

$2S_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2SO_{3(g)}$ $\quad \Delta H = -790$ kJ

What is the value of the change in the heat content when 0.75 g of sulphur is burnt ? .....

(a) +23 kJ (b) –9.26 kJ

(c) –18 kJ (d) +12 kJ

5 Nitrogen reacts with oxygen according to the following thermochemical equation :

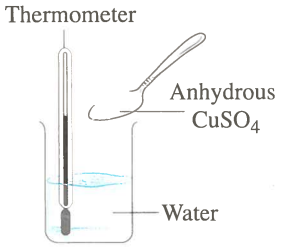
$N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)}$ $\quad \Delta H = +66$ kJ

What is the change in enthalpy on mixing 2 mol of nitrogen with 2 mol of oxygen ? .....

(a) +132 kJ (b) +66 kJ

(c) +33 kJ (d) +16.5 kJ

6 From the opposite figure :
On dissolving anhydrous copper (II) sulphate in water, the reading of thermometer raises..
Which of the following choices represents both the type of this process, and its ΔH sign ? .....



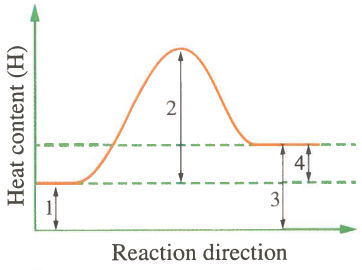
Choices	(a)	(b)	(c)	(d)
Type of the process	Endothermic	Endothermic	Exothermic	Exothermic
ΔH sign	Positive	Negative	Negative	Positive

7 Which of the following statements represents the type of the chemical reaction which happens when a match head is rubbed against a rough surface ? .....

(a) Endothermic reaction due to using energy on rubbing the match head.
(b) Endothermic reaction due to releasing energy on burning the wooden match.
(c) Exothermic reaction due to using energy on rubbing the match head.
(d) Exothermic reaction due to releasing energy on rubbing the wooden match.

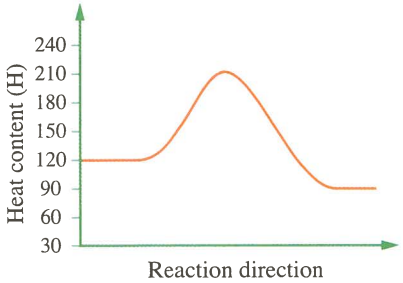
8 What is the number which indicates the heat of the reaction illustrated by the opposite figure ? .....

(a) 1 (b) 2
(c) 3 (d) 4



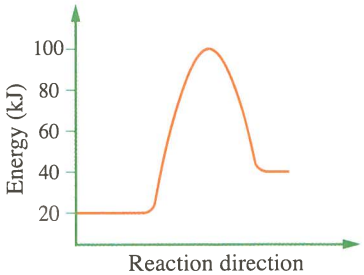
9 The opposite graphical figure represents the thermal change which occurs during a chemical reaction.. What is the value of ΔH of this reaction ? .....

(a) –120 kJ (b) –30 kJ
(c) +30 kJ (d) +120 kJ

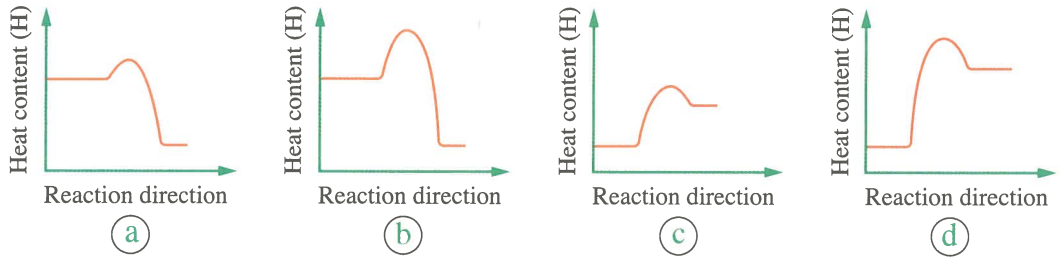


10 The opposite graphical figure shows the energy diagram of one of the chemical reactions..
Which of the following choices represents both the type of the reaction, and the value of its ΔH ?.....

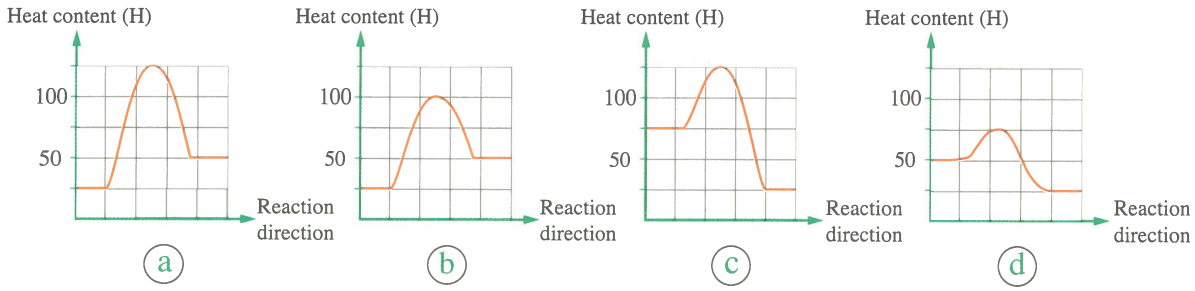
Choices	(a)	(b)	(c)	(d)
Type of the reaction	Endothermic	Exothermic	Endothermic	Exothermic
ΔH value	+20 kJ	+20 kJ	–20 kJ	–20 kJ



11 Which of the following energy diagrams represents a thermal decomposition reaction which takes place in shorter time ? .....



12 Which of the following diagrams expresses an exothermic reaction that has the least ΔH value (with negative sign) ? .....



13 Which of the following statements represents correctly the endothermic reaction ? .....

(a) The bonds in the products molecules are stronger than those in reactants molecules.
(b) The bonds in the reactants molecules are stronger than those in products molecules.
(c) The heat content of the products is lower than that of the reactants.
(d) It occurs spontaneously in low temperatures.

14 In the process : $N_2 + Energy \longrightarrow N + N$
Which of the following statements represents the previous process ? .....

(a) Breaking bonds takes place, this process is endothermic.
(b) Breaking bonds takes place, this process is exothermic.
(c) Forming bonds takes place, this process is exothermic.
(d) Forming bonds takes place, this process is endothermic.

15 The reaction : $H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$ is exothermic, because .....

(a) the absorbed energy during breaking the bonds is higher than that produced during bond formation.
(b) the produced energy during bond formation is higher than that required to break the bonds.
(c) number of broken bonds is higher than that of formed bonds.
(d) number of formed bonds is higher than that of broken bonds.

16 The plant cells use light energy to carry out the photosynthesis process..
Which of the following statements represents photosynthesis reaction ? .....

(a) It is an energy absorbing process, as the energy released during the formation of the bonds is less than the energy required to break the bonds.

(b) It is an energy absorbing process, as the energy released during the formation of the bonds is greater than the energy required to break the bonds.

(c) It is an energy releasing process, as the energy released during the formation of the bonds is less than the energy required to break the bonds.

(d) It is an energy releasing process, as the energy released during the formation of the bonds is greater than the energy required to break the bonds.

17 In the reaction : $A_{2(g)} \longrightarrow 2A_{(g)}$, $\Delta H = X$ kJ/mol
What is the value of ΔH of the reaction : $4A_{(g)} \longrightarrow 2A_{2(g)}$? .....

(a) $(2X)$ kJ (b) $(-2X)$ kJ (c) $\left(\frac{X}{2}\right)$ kJ (d) $\left(-\frac{X}{2}\right)$ kJ

18 In the thermal reaction : $R_2 + Q_2 \longrightarrow 2RQ$
Which of the following choices represents the reaction which produces higher amount of heat ? .....

Choices	Bond in R_2	Bond in Q_2	Bond in RQ
(a)	Strong	Strong	Strong
(b)	Strong	Strong	Weak
(c)	Weak	Weak	Strong
(d)	Weak	Weak	Weak

19 Liquid water is formed from two elements in three steps, which are :
(1) $2H_{2(g)} + O_{2(g)} \longrightarrow 4H_{(g)} + 2O_{(g)}$ (2) $4H_{(g)} + 2O_{(g)} \longrightarrow 2H_2O_{(v)}$
(3) $2H_2O_{(v)} \longrightarrow 2H_2O_{(\ell)}$
What is (are) the step(s) which is (are) considered exothermic ? .....

(a) (2) only. (b) (1) and (2) only.
(c) (2) and (3) only. (d) (1), (2) and (3).

20 Ethane gas reacts with chlorine gas, according to the equation :

What is the value of ΔH of this reaction ? .....

(a) +117 kJ/mol (b) +1420 kJ/mol
(c) – 1420 kJ/mol (d) – 117 kJ/mol

Bond	Average bond energy (kJ/mol)
C – Cl	340
C – C	346
C – H	413
Cl – Cl	240
H – Cl	430

21 What is the value of ΔH of this reaction : $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$? .....

Knowing that the values of the average bond energies are :

[(H – H) = 432 kJ/mol , (O = O) = 498 kJ/mol , (O – H) = 467 kJ/mol]

(a) +467 kJ (b) –506 kJ (c) +485 kJ (d) 0

22 Assisted by the values of the average bond energies shown in the following table :

Bond	Cl – Cl	H – Cl	C – H	C – Cl
Average bond energy (kJ/mol)	240	430	413	340

What is the value of ΔH of this reaction : $CH_4 + 3Cl_2 \longrightarrow CHCl_3 + 3HCl$? .....

(a) +351 kJ/mol (b) –351 kJ/mol

(c) +430 kJ/mol (d) – 430 kJ/mol

23 From the reaction and the table :

$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$

Bond	Bond energy (kJ/mol)
Cl – Cl	240
H – H	432
H – Cl	430

We conclude that .....

(a) ΔH of the reaction equals – 1442 kJ

(b) ΔH of the reaction equals – 348 kJ

(c) the energy resulted from formation of 1 mol of products is + 94 kJ

(d) the energy resulted from formation of 1 mol of products is + 188 kJ

24 $PCl_{5(g)}$ decomposes by heat to $PCl_{3(g)}$ and chlorine gas,

(P–Cl) = 330 kJ/mol
(Cl–Cl) = 240 kJ/mol

ΔH of this reaction is .....

(a) –90 kJ/mol (b) –420 kJ/mol

(c) +420 kJ/mol (d) +90 kJ/mol

Essay questions and problems

25 Illustrate by drawing the energy diagram of each of the following reactions :

(1) $2S_{(s)} + 3O_{2(g)} \longrightarrow 2SO_{3(g)}$ ΔH = –792 kJ

(2) $CS_{2(g)} + 3Cl_{2(g)} \longrightarrow CCl_{4(g)} + S_2Cl_{2(g)}$ ΔH = +238 kJ/mol

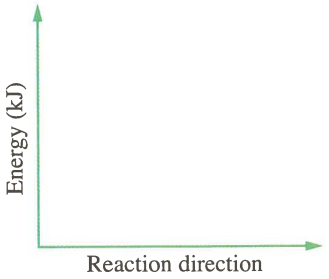
26 Hydrazine N_2H_4 is used as fuel in space rockets when it reacts with oxygen gas or with fluorine gas according to the following equations :

① $N_2H_{4(\ell)} + O_{2(g)} \longrightarrow N_{2(g)} + 2H_2O_{(v)}$ $\Delta H = -622$ kJ/mol

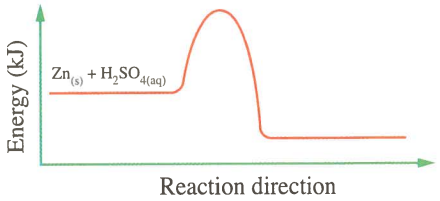
② $N_2H_{4(\ell)} + 2F_{2(g)} \longrightarrow N_{2(g)} + 4HF_{(g)}$ $\Delta H = -1166$ kJ/mol

(1) Represent reaction ① by completing the opposite diagram of the reaction.

(2) Which of these two reactions is preferred to be used in providing energy for space rockets ? Explain.



27 The opposite energy diagram represents the reaction of zinc with dilute sulphuric acid :



(1) Introduce to the opposite energy diagram :

1– The formulas of the products, with writing their physical states.

2– An arrow to represent the change in enthalpy.

(2) Is this reaction exothermic or endothermic ? Explain.

28 In the reaction : $X_2 + Y_2 \longrightarrow 2XY$

If the bonds (X – X) and (Y – Y) are weak bonds and (X – Y) is a strong bond..

What is the type of this reaction ? Why ?

29 Calculate ΔH of the following reaction :

$$H_{2(g)} + Br_{2(g)} \longrightarrow 2HBr_{(g)}$$

Assisted by the values of the average bond energies :

(H – H) = 432 kJ/mol , (Br – Br) = 193 kJ/mol , (H – Br) = 366 kJ/mol

30 Calculate the change in enthalpy of the following reaction :

$$C_2H_{2(g)} + \frac{5}{2}O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)} + H_2O_{(v)}$$

Where the average bond energy of :

(C – H) = 413 kJ/mol , (C ≡ C) = 835 kJ/mol

(O – H) = 467 kJ/mol , (C = O) = 803 kJ/mol , (O = O) = 498 kJ/mol

31 **In the reaction :** $H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$

(1) Calculate ΔH of this reaction (in kJ),

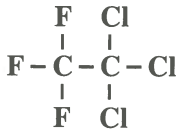
Knowing that the average bond energies (in kcal/mol) are :

(H – H) = 104 , (Cl – Cl) = 58 , (H – Cl) = 103

(2) Is this reaction exothermic or endothermic ? Give reason.

(3) Draw the energy diagram of this reaction.

32 **The opposite structural formula represents one of the chlorofluorocarbon compounds which cause decaying of ozone layer due to the action of UV-rays.**



(1) Calculate the amount of the heat absorbed during breaking bonds of one mole of the compound.

(2) Why are chlorine atoms released instead of fluorine atoms when UV-rays fall on the compound ? "knowing that the absorbed UV-rays energy in one mole of this compound is 400 kJ"

(C–Cl) = 340 kJ/mol
(C–C) = 346 kJ/mol
(C–F) = 450 kJ/mol

33 **From the reaction :** $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$ $\Delta H = -89$ kJ

Calculate the average bond energy of (N – H),

knowing that the average bond energies are :

(H – H) = 432 kJ/mol , (N ≡ N) = 941 kJ/mol

34 "The value of (S = O) bond energy in SO_3 differs from that of SO_2",

Illustrate that by using chemical calculations on the following reaction :

$$2O=S=O_{(g)} + O=O_{(g)} \xrightarrow{\Delta} 2O=\underset{\underset{O}{\|}}{S}=O_{(g)} \quad \Delta H = -196 \text{ kJ}$$

Knowing that :

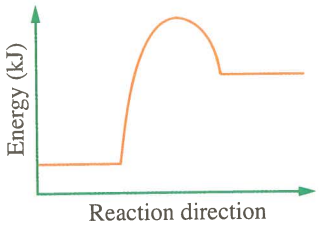
Bond	S=O in (SO_2)	O = O
Average bond energy (kJ/mol)	534	498

New types of questions ?

Answered

Choosing two out of five choices questions :

1 What are the two equations which can be represented by the opposite energy diagram ? .....



(a) $NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(\ell)}$

(b) $CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)}$

(c) $2MgO_{(s)} \longrightarrow 2Mg_{(s)} + O_{2(g)}$

(d) $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(v)}$

(e) $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(\ell)}$

2 Hydrogen gas reacts with chlorine gas producing hydrogen chloride gas.. What are the two choices which represent the data that should be provided to calculate ΔH of this reaction ? .....

(a) (H – H) average bond energy and (H – Cl) average bond energy.

(b) The heat content of H_2 and Cl_2

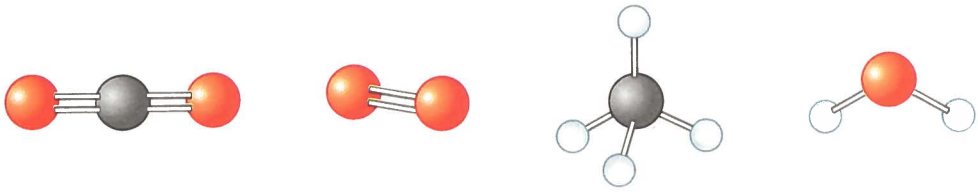
(c) The heat content of HCl

(d) (Cl – Cl) bond energy.

(e) Heat of formation of HCl

The sketch questions :

3 The molecules which are illustrated by the following figures represent the reactants and the products of an exothermic reaction referred to by the number [1] , [2] , [3] and [4] with no particular order :



[1] [2] [3] [4]

Choose from the opposite table the suitable answer for each of the questions (A) and (B) :

3	4	5
6	7	8

(A) What is the sum of the two numbers which refer to the reactants in this reaction ? .....

(B) What is the sum of the numbers of the coefficients of the products in the balanced equation representing this reaction ? .....

Unit 4

Chapter Two

Lesson 1

From Heat changes accompanying physical and chemical changes

Until Before heat changes accompanying chemical changes

Heat changes accompanying physical and chemical changes

* The calculation of the change in heat content is of a great importance, **where :**

- The burning of different fuels, helps us during designing engines to know which type of fuel is more suitable.
- The burning of different materials, helps firemen in identifying and choosing the most suitable method to put off fires.

☆ The change in the heat content differs according to the type of change **(physical or chemical)**.

Heat changes accompanying physical changes

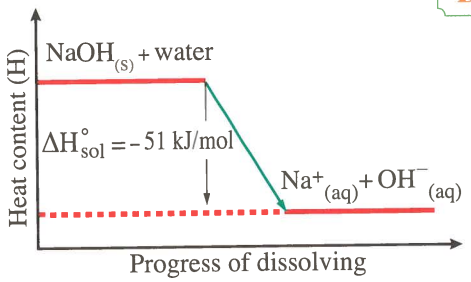
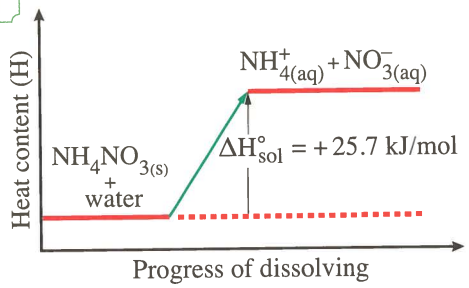
* **Examples of heat changes accompanying physical changes are :**

1. Standard heat of solution.
2. Standard heat of dilution.

1 Standard heat of solution ΔH°_{sol}

- On dissolving a solid substance in a liquid, this process is accompanied by **an increase** or **a decrease** in the temperature of the resulted solution.

By dissolving

Sodium hydroxide (NaOH) in water, the temperature of the solution increases	Ammonium nitrate (NH_4NO_3) in water, the temperature of the solution decreases
The solution is called	
Exothermic solution , and its ΔH°_{sol} has **negative sign**	**Endothermic** solution , and its ΔH°_{sol} has **positive sign**
Equation	
$NaOH_{(s)} \xrightarrow{water} Na^+_{(aq)} + OH^-_{(aq)}$, $\Delta H^\circ_{sol} = -51$ kJ/mol	$NH_4NO_{3(s)} \xrightarrow{water} NH^+_{4(aq)} + NO^-_{3(aq)}$, $\Delta H^\circ_{sol} = +25.7$ kJ/mol
Diagram	
	
Sodium hydroxide is an exothermic solution	*Ammonium nitrate is an endothermic solution*

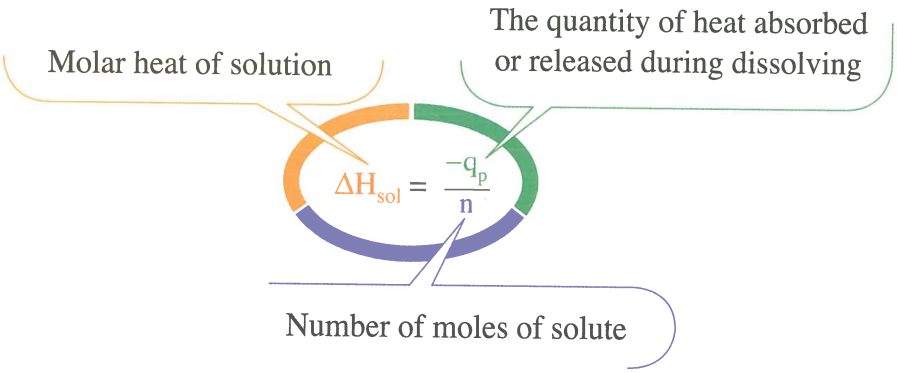
- **Heat of solution ΔH_{sol}** is the quantity of heat released or absorbed which accompanying the dissolving process to obtain saturated solution.
- **Standard heat of solution ΔH°_{sol}** is the quantity of heat absorbed or released on dissolving one mole of solute in a certain amount of solvent to obtain a saturated solution under standard conditions.

The heat of solution can be calculated by the following relation :

Quantity of heat released or gained (q) under constant pressure (p)	Mass of solution	Specific heat of solvent	Change in temperature $\Delta T = T_2 - T_1$
q_p	m	c	ΔT
(J)	(g)	(J/g.°C)	(°C)

- **Molar heat of solution** is the heat change resulting from dissolving one mole of the solute in an amount of solvent to form one liter of the solution.

* If the amount of solute does not equal 1 mol, **we can calculate the molar heat of solution from the relation :**



What is meant by

1 Standard heat of solution of lithium bromide is –49 kJ/mol ?

That means

The quantity of heat released on dissolving 1 mol of lithium bromide in a certain amount of solvent to obtain a saturated solution under standard conditions equals 49 kJ

2 Molar heat of solution of silver iodide is +84.4 kJ/mol ?

That means

The quantity of heat absorbed on dissolving 1 mol of silver iodide in a certain amount of solvent to form 1 L of the solution equals 84.4 kJ

Examples

1 By dissolving 80 g of NaOH in an amount of water to produce 1 L of a solution, the temperature increased from 20°C to 44.4°C, **Calculate :** [Na = 23 , O = 16 , H = 1]

(1) The heat of solution.

(2) The molar heat of solution.

(3) Is this solution exothermic or endothermic ?

Solution

(1) $m_{(NaOH)} = 80\ g$, $c = 4.18\ J/g.°C$, $m_{(solution)} = 1000\ g$, $T_1 = 20°C$, $T_2 = 44.4°C$

$q_p = m\ c\ \Delta T = 1000 \times 4.18 \times (44.4 - 20) = +101992\ J = +101.992\ kJ$

(2) The molar mass of NaOH = 23 + 16 + 1 = 40 g/mol

$$\text{Number of moles of NaOH} = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{80}{40} = 2\ mol$$

$$\Delta H_{sol} = \frac{-q_p}{n} = \frac{-101.992}{2} = -51\ kJ/mol$$

(3) The solution is exothermic.

2 When 80 g of ammonium nitrate are dissolved in an amount of water to form 1 L of solution, the temperature decreases from 20°C to 14°C : [N = 14 , O = 16 , H = 1]

(1) Calculate the heat change accompanying this dissolving process.

(2) Does this heat change express the molar heat of solution ? Why ?

(3) Is this solution exothermic or endothermic ?

Solution

(1) $m_{(NH_4NO_3)} = 80$ g , $c = 4.18$ J/g.°C , $m_{(solution)} = 1000$ g , $T_1 = 20°C$, $T_2 = 14°C$

$q_p = m\,c\,\Delta T$

$= 1000 \times 4.18 \times (14 - 20) = -25080$ J $= -25.08$ kJ

$\because$ The molar mass of $NH_4NO_3 = 14 + (4 \times 1) + 14 + (3 \times 16) = 80$ g/mol

$\therefore$ Number of moles of $NH_4NO_3 = \dfrac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$

$= \dfrac{80}{80} = 1$ mol

$\therefore \Delta H_{sol} = \dfrac{-q_p}{n}$

$= \dfrac{-(-25.08)}{1} = +25.08$ kJ/mol

(2) **Yes**, the heat change is expressing the molar heat of solution /

Because :

- The amount of solute (ammonium nitrate) is 1 mol
- The volume of the resulting solution is 1 L

(3) The solution is endothermic.

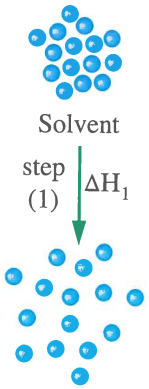
Explanation of the source of the heat of solution

Dissolving process is affected by three forces, which are :

- Attraction forces between particles (molecules) of solvent.
- Attraction forces between particles (molecules) of solute.
- Attraction forces between particles (molecules) of solvent and solute.

So, the dissolving process takes place in three steps, **which are :**

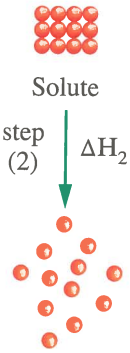
1 Separating solvent particles



It is an endothermic process, because an amount of energy is **absorbed** to overcome the attraction forces between the particles of the solvent with each other

(ΔH_1 has positive sign)

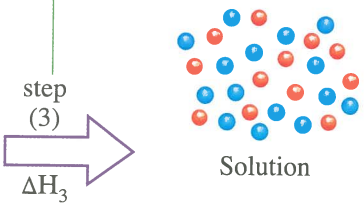
2 Separating solute particles



It is an endothermic process, because an amount of energy is **absorbed** to overcome the attraction forces between the particles of the solute with each other

(ΔH_2 has positive sign)

3 Combination of solvent particles with solute particles (Dissolving process)



It is an exothermic process, because an amount of energy is **released** when solvent particles are combined with the particles of solute

(ΔH_3 has negative sign)

The change in heat content of this process is represented by

* **The value of heat of solution (ΔH_{sol}) equals the sum of the change in heat content of the three steps :**

$$\Delta H_{sol} = \Delta H_1 + \Delta H_2 + \Delta H_3$$

* **If the solvent is water,** so the dissolving process is called **hydration** which is the attaching of the dissociated ions or molecules of solute with water molecules.
* The amount of heat energy released from attaching ions or molecules of solute with water molecules is called **hydration energy.**

What is meant by :

The hydration energy of silver ions equals –510 kJ/mol ?

This means that the amount of heat energy released from attaching 1 mol of silver ions with water molecules equals 510 kJ

The type of the dissolving process (exothermic or endothermic) is determined by the sign of the value of its (ΔH_{sol}) :

If

$(\Delta H_1 + \Delta H_2) \leqslant \Delta H_3$

So,

$\Delta H_{sol} \leqslant 0$

(Negative sign)

And the solution is

Exothermic

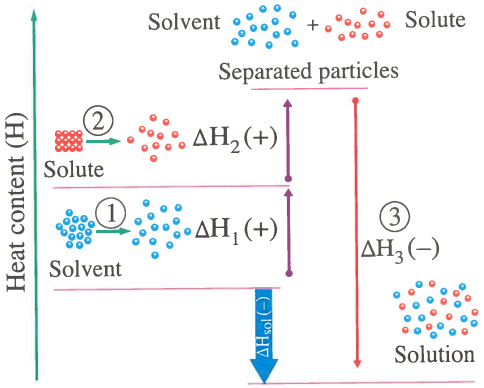


Diagram of an exothermic solution

$(\Delta H_1 + \Delta H_2) \geqslant \Delta H_3$

$\Delta H_{sol} \geqslant 0$

(Positive sign)

Endothermic

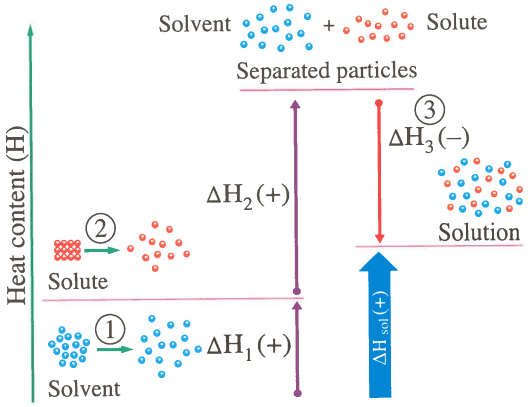


Diagram of an endothermic solution

Example

If 1 mol of caustic potash is dissolved in water, where the heat which is required to separate solvent particles is 50 kJ, the heat required to dissociate solute particles is 100 kJ, and the hydration energy is 400 kJ, **calculate the heat of solution of** caustic potash in water, **illustrating** whether the solution is exothermic **or** endothermic **with mentioning the reason.**

Solution

$\Delta H_1 = +50$ kJ , $\Delta H_2 = +100$ kJ , $\Delta H_3 = -400$ kJ

$\Delta H_{sol} = \Delta H_1 + \Delta H_2 + \Delta H_3$

$= 50 + 100 + (-400) = -250$ kJ

$\therefore$ The solution is exothermic / As the energy released from the hydration process (ΔH_3) is greater than the sum of the energies absorbed to separate the particles of each of the solute and the solvent from each other ($\Delta H_1 + \Delta H_2$) .

2 Standard heat of dilution ΔH°_{dil}

* **Standard heat of dilution ΔH°_{dil}** is the quantity of released or absorbed heat for each one mole of solute when diluting the solution from a high concentration to another lower concentration with the condition of being in its standard state.

What is meant by

The standard heat of dilution of sodium hydroxide solution is –4.5 kJ/mol ?

This means that the heat released from each 1 mol of sodium hydroxide solution when it's diluted from a higher concentration to a lower concentration at standard conditions equals 4.5 kJ

Application

- When 1 mol of sodium hydroxide $NaOH_{(s)}$ is dissolved in different amounts of water $H_2O_{(\ell)}$, the heat of the solution differs with the difference of the amount of water, **as in the following equations :**

* $NaOH_{(s)} + 5H_2O_{(\ell)} \longrightarrow NaOH_{(aq)}$ $\quad \Delta H_1 = -37.8$ kJ/mol

* $NaOH_{(s)} + 200H_2O_{(\ell)} \longrightarrow NaOH_{(aq)}$ $\quad \Delta H_2 = -42.3$ kJ/mol

- **It is observed that** ΔH_2 value $\geqslant \Delta H_1$ value
- **It is concluded that** the amount of released or absorbed energy increases by adding another amount of water (solvent).

Dilution process takes place in two opposite steps according to the energy, which are :

① Separation energy

It is an endothermic process

Because **separating the ions** or **particles of the solute** from each other in the concentrated solution needs absorbing an amount of energy

② Attaching energy

It is an exothermic process

Because **the ions** or **particles** of solute **are attached** to a greater number of molecules of the solvent, which leads to releasing an amount of energy

The heat of dilution is the sum of those two energies (separation and attaching).

Note

Dilution process is accompanied in its beginning by absorbing an amount of energy, as increasing the number of water molecules during dilution leads to separating the ions or the molecules of the solute from each other in the higher concentrated solution which requires absorbing an amount of energy

Questions ?

UNIT 4 ..... Chapter Two Lesson 1

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Choose the correct answer :

(1) Dissolving process is called hydration when the solvent is .....

a. benzene. b. oil. c. alcohol. d. water.

(2) Hydration process is .....

a. exothermic process. b. endothermic process.

c. may be exo/endo-thermic. d. not accompanied by heat change.

(3) In the following thermochemical equation :

$$NH_4NO_{3(s)} \xrightarrow{water} NH^+_{4(aq)} + NO^-_{3(aq)} \quad , \quad \Delta H^\circ = +25.7 \text{ kJ/mol}$$

The heat change accompanying this process is called the standard heat of .....

a. formation. b. combustion. c. solution. d. neutralization.

(4) Dilution process is accompanied with .....

a. releasing heat. b. absorbing heat.

c. releasing or absorbing heat. d. no heat change.

2 Give reasons for :

(1) Dissolving sodium hydroxide (caustic soda) in water is accompanied with raising the temperature of the solution.

(2) When ammonium nitrate is dissolved in water, the solution's temperature decreases.

(3) Dissolving process is accompanied with a heat change.

(4) At the beginning of dilution, the process is accompanied with absorbing energy.

3 What is meant by ... ?

(1) Standard heat of solution of lithium bromide is – 49 kJ/mol

(2) Molar heat of solution of sulphuric acid is –71.06 kJ/mol

(3) The hydration energy of silver ions is –510 kJ/mol

(4) The standard heat of dilution of sodium hydroxide solution is – 4.5 kJ/mol

Steady

Open book questions

Answered

Multiple choice questions

1 Which of the following equations represents the standard heat of solution of silver nitrate salt in water ? .....

(a) $AgNO_{3(aq)} \xrightarrow{water} Ag^{+}_{(aq)} + NO^{-}_{3(aq)}$ $\Delta H^{\circ}_{sol} = +36.91$ kJ/mol

(b) $AgNO_{3(s)} \xrightarrow{water} Ag^{+}_{(aq)} + NO^{-}_{3(aq)}$ $\Delta H^{\circ}_{f} = +36.91$ kJ/mol

(c) $AgNO_{3(s)} \xrightarrow{water} Ag^{-}_{(aq)} + NO^{+}_{3(aq)}$ $\Delta H^{\circ}_{sol} = +36.91$ kJ/mol

(d) $AgNO_{3(s)} \xrightarrow{water} Ag^{+}_{(aq)} + NO^{-}_{3(aq)}$ $\Delta H^{\circ}_{sol} = +36.91$ kJ/mol

2 When 8 g of ammonium nitrate salt are added to a coffee cup calorimeter which contains 125 g of water whose temperature is 24.2°C, the temperature of the solution drops to 18.2°C, so if the specific heat of the solution is 4.2 J/g.°C, What is the molar heat of the solution ? ..... [N = 14 , H = 1 , O = 16]

(a) +33.5 kJ/mol (b) +39.5 kJ/mol (c) +32.2 kJ/mol (d) +37.3 kJ/mol

3 Dissolving magnesium chloride in water to form a saturated solution is represented by the following equation :

$$MgCl_{2(s)} \xrightarrow{water} Mg^{2+}_{(aq)} + 2Cl^{-}_{(aq)} \qquad \Delta H^{\circ}_{sol} = -155 \text{ kJ/mol}$$

What is the quantity of heat released when 19 g of magnesium chloride (its molar mass is 95 g/mol) are dissolved in water to obtain a saturated solution ? .....

(a) +31 kJ (b) –31 kJ (c) +755 kJ (d) –755 kJ

4 Which of the following choices represents the correct signs of ΔH values of the following processes ? .....

Choices	Separation of solute particles	Separation of solvent particles	Separation of solvent particles from solute particles
(a)	+	+	+
(b)	+	+	–
(c)	–	–	+
(d)	–	–	–

5 Which of the following its value is the greatest in an exothermic solution ? .....

(a) ΔH_1 (b) ΔH_2 (c) ΔH_3 (d) $\Delta H_1 + \Delta H_2$

6 **Molar heat of solution of lithium bromide salt LiBr is represented by the following equation :** $LiBr_{(s)} \xrightarrow{water} Li^+_{(aq)} + Br^-_{(aq)}$ $\Delta H^\circ_{sol} = -48.78$ **kJ/mol**

Which of the following statements is correct ? .....

(a) It is an exothermic solution, as the sum of the energies of separation of each of solute particles and solvent particles from each other is higher than the hydration energy.

(b) It is an endothermic solution, as the sum of the energies of separation of each of solute particles and solvent particles from each other is higher than the hydration energy.

(c) It is an exothermic solution, as the sum of the energies of separation of each of solute particles and solvent particles from each other is lower than the hydration energy.

(d) It is an endothermic solution, as the sum of the energies of separation of each of solute particles and solvent particles from each other is lower than the hydration energy.

7 **If you know that the standard heat of solution of calcium chloride $CaCl_2$ salt equals –120 kJ/mol, Which of the following relations is correct ?** .....

(a) $\Delta H_1 + \Delta H_2 = \Delta H_3$

(b) $\Delta H_1 + \Delta H_2 < \Delta H_3$

(c) $\Delta H_1 + \Delta H_3 > \Delta H_2$

(d) $\Delta H_1 + \Delta H_2 > \Delta H_3$

8 **If you know that ΔH°_{sol} of sodium chloride equals +1 kJ/mol.. Which of the following choices is correct ?** .....

Choices	Type of solution	Relation between energies
(a)	Exothermic	$\Delta H_1 + \Delta H_2 > \Delta H_3$
(b)	Exothermic	$\Delta H_1 + \Delta H_2 < \Delta H_3$
(c)	Endothermic	$\Delta H_1 + \Delta H_2 > \Delta H_3$
(d)	Endothermic	$\Delta H_1 + \Delta H_2 < \Delta H_3$

9 **If you know that the standard heat of solution of potassium iodide salt equals +14 kJ/mol, Which of the following statements is impossible to be correct ?** .....

(a) Dissolving KI salt in water is exothermic.

(b) Hydration energy of K^+ ions equals –322 kJ/mol

(c) Hydration energy of I^- ions equals –293 kJ/mol

(d) Attaching energy of K^+ and I^- ions to water is less than the separation energies of the ions of KI salt and the molecules of water from each other.

10 By comparing ΔH°_{sol} of the reactions (1) and (2) :

(1) $NH_4NO_{3(s)} \xrightarrow{water} NH^+_{4(aq)} + NO^-_{3(aq)}$ $\Delta H^\circ_{sol} = +25.7$ kJ/mol

(2) $NaF_{(s)} \xrightarrow{water} Na^+_{(aq)} + F^-_{(aq)}$ $\Delta H^\circ_{sol} = +0.9$ kJ/mol

It is concluded that in .....

(a) reaction (2), the separation energy of solute particles is almost equal to the hydration energy.

(b) reaction (2), the separation energy of solute particles is lower than the hydration energy.

(c) reaction (1), the separation energy of solute particles is lower than the hydration energy.

(d) reaction (1), the separation energy of solute particles is almost equal to the hydration energy.

Questions marked by this mark are for the superiors and their ideas are explained in the answers

11 In the opposite equation : $H_2SO_{4(aq)}$ (98%) + $nH_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$ (30%)

The heat change accompanied with this process is called the heat of .....

(a) formation. (b) combustion. (c) solution. (d) dilution.

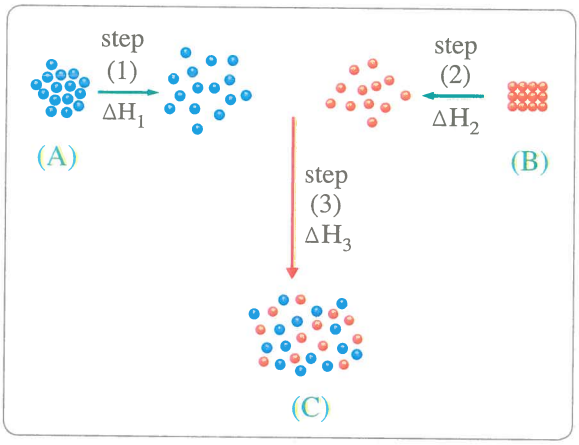
Essay questions

12 Study the opposite figure which explains the source of the heat of solution, then answer :

(1) What do (A), (B) and (C) represent ?

(2) Is step (2) endothermic or exothermic ? Give reason.

(3) What do you conclude when : $(\Delta H_1 + \Delta H_2) < \Delta H_3$?



13 Why is the heat change produced from dissolving 58.5 g of sodium chloride salt in pure water to form 1000 mL of salt solution called the molar heat of solution ?

[Na = 23 , Cl = 35.5]

14 **Write the thermochemical equation** which represents dissolving calcium fluoride salt in water, knowing that the change in the standard enthalpy of solution of it equals –51 kJ/mol

15 **Calculate the molar heat of solution** of calcium chloride $CaCl_2$ in water, knowing that the change in heat content produced from dissolving 1.1 g of this salt equals –0.8 kJ

[Ca = 40 , Cl = 35.5]

16 **Calculate the change in heat content** produced from dissolving 2.8 g of caustic potash KOH in water, where the molar heat of solution of caustic potash is –58.5 kJ/mol

[K = 39 , O = 16 , H = 1]

17 **Calculate the molar heat of solution of** lithium bromide (LiBr = 86.84 g/mol), knowing that by dissolving 17.368 g of it in an amount of water to form 1 L of the solution, the temperature rises by 2.3°C

18 **When 170 g of silver nitrate are dissolved in an amount of water whose temperature is 25°C to form a liter of solution, the temperature becomes 16.17°C :**

(1) Calculate the change in heat content of the solution.

(2) Does the change in heat content of this solution represent the molar heat of solution ? Explain.

[Ag = 108 , N = 14 , O = 16]

New types of questions ?

Answered

Choosing two out of five choices questions :

1 What are the two processes whose enthalpies changes have positive signs ? .....

(a) $Mg^{2+}_{(g)} + H_2O_{(\ell)} \longrightarrow Mg^{2+}_{(aq)}$

(b) $H_2O_{(\ell)} \longrightarrow H_2O_{(v)}$

(c) $NH^{+}_{4(aq)} + NO^{-}_{3(aq)} \longrightarrow NH_4NO_{3(s)}$

(d) $NaCl_{(s)} \longrightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$

(e) $NaOH_{(s)} \longrightarrow NaOH_{(aq)}$

2 The solution of sodium chloride in water is endothermic, and its molar heat of solution equals 3 kJ/mol.. What are the two equations which are used in the calculation of the molar heat of solution of sodium chloride ? .....

(a) $NaCl_{(s)} + H_2O_{(\ell)} \longrightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$ $\Delta H = +3$ kJ/mol

(b) $NaCl_{(s)} \longrightarrow Na^{+}_{(g)} + Cl^{-}_{(g)}$ $\Delta H = +786$ kJ/mol

(c) $H_2O_{(\ell)} + Na^{+}_{(g)} \longrightarrow Na^{+}_{(aq)}$ $\Delta H = -422$ kJ/mol

(d) $H_2O_{(\ell)} + Na^{+}_{(g)} + Cl^{-}_{(g)} \longrightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$ $\Delta H = -783$ kJ/mol

(e) $H_2O_{(\ell)} + Cl^{-}_{(g)} \longrightarrow Cl^{-}_{(aq)}$ $\Delta H = -340$ kJ/mol

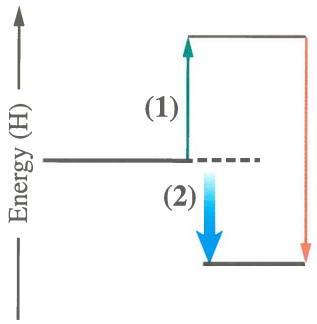
Filling in the spaces questions :

3 Fill in the spaces from the given choices :

The opposite figure represents the diagram of an exothermic solution reaction,

in which (1) represents .....

, while (2) represents .....



(a) ΔH_3

(b) ΔH°_{sol}

(c) $\Delta H_1 + \Delta H_2 + \Delta H_3$

(d) $\Delta H_2 + \Delta H_3$

(e) $\Delta H_1 + \Delta H_2$

(f) $\Delta H_1 + \Delta H_3$

Unit 4

Chapter Two

Lesson 2

From Heat changes accompanying chemical changes

Until The end of the chapter

Heat changes accompanying chemical changes

* There are many forms of **the heat changes** accompanying the chemical reactions, **among them are :**

1 **Standard heat of combustion.**

2 **Standard heat of formation.**

1 Standard heat of combustion ΔH_c°

- **Combustion** is the fast combination between the substance and oxygen.
- The complete combustion of some elements and compounds releases a large amount of energy in the form of heat or light or both of them.

The quantity of heat released when any substance combusts completely in an excess amount of oxygen is known as **Heat of combustion ΔH_c**

- If the combustion takes place under standard conditions, it is called Standard heat of combustion ΔH_c°

☆ The combustion of most of organic substances (like fuel and glucose) produces :

- Water (H_2O) whether liquid or vapour.
- Carbon dioxide (CO_2).
- Heat energy.

Note

Combustion reactions are always exothermic, so ΔH_c value always has negative sign

What is meant by

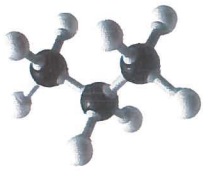
The standard heat of combustion of glucose equals –2808 kJ/mol ?

This means that the heat released when one mole of glucose is completely combusted in an excess amount of oxygen under standard conditions equals 2808 kJ

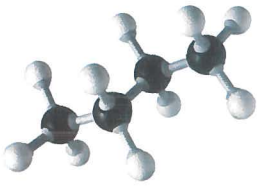
Examples for combustion reactions

1 Combustion of stove gas (Butagas) :

- Stove gas (Butagas) is a mixture of :
  - Propane C_3H_8
  - Butane C_4H_{10}



Molecular structure of propane C_3H_8

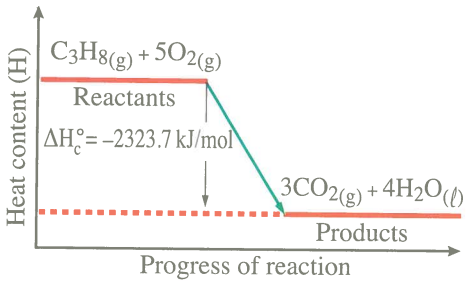


Molecular structure of butane C_4H_{10}

- This combustion reaction produces a large amount of heat which is used in cooking food and has other uses.

The following equation and the opposite energy diagram represent the complete combustion of propane gas :

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(\ell)} \quad , \quad \Delta H_c^\circ = -2323.7 \text{ kJ/mol}$$



Energy diagram of combustion of propane gas

2 Combustion of glucose inside the body of the living organism :

- It is one of the very important combustion reactions as it provides the living organisms with the needed energy to perform their vital processes.

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(\ell)} \qquad \Delta H_c^\circ = -2808 \text{ kJ/mol}$$

Examples

1 If the heat of combustion of one mole of ethanol (C_2H_5OH) is –1367 kJ/mol :

(1) Write the thermochemical equation which expresses that reaction.

(2) Calculate the energy released from the complete combustion of 100 g of ethanol.

[C = 12 , H = 1 , O = 16]

Solution

(1) $C_2H_5OH_{(\ell)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(\ell)} \qquad \Delta H_c^\circ = -1367$ kJ/mol

(2) Molar mass of $C_2H_5OH = (2 \times 12) + (5 \times 1) + 16 + 1 = 46$ g/mol

$$\text{Number of moles of } C_2H_5OH = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{100}{46} = 2.17 \text{ mol}$$

$\because \Delta H_c^\circ = \dfrac{-q_p}{n}$

$\therefore q_p = -(\Delta H_c^\circ \times n) = -(-1367 \times 2.17)$

$= +2966.39$ kJ

2 **Calculate the standard heat of combustion of** propane C_3H_8, **knowing that** the change in the heat content which accompanies the combustion of 8 g of propane in excess amount of oxygen is – 422.49 kJ [C = 12 , H = 1]

Solution

C_3H_8	⟶	ΔH_c
8 g		– 422.49 kJ
$(12 \times 3) + (1 \times 8) = 44$ g/mol		? kJ/mol

$$\Delta H_c^\circ = \frac{44 \times -422.49}{8} = -2323.7 \text{ kJ/mol}$$

3 **Calculate the mass of** glucose which is burnt to raise the temperature of 100 g of water from 20°C to 25°C (assuming no heat is lost), **according to the equation :**

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(\ell)} \qquad \Delta H_c^\circ = -2808 \text{ kJ/mol}$$

[$C_6H_{12}O_6$ = 180 g/mol]

Solution

$$q_p = m\,c\,\Delta T = 100 \times 4.18 \times (25 - 20) = 2090 \text{ J} = 2.09 \text{ kJ}$$

$$\because \Delta H_c^\circ = \frac{-q_p}{n}$$

$$\therefore n = \frac{-q_p}{\Delta H_c^\circ} = \frac{-2.09}{-2808} = 7.4 \times 10^{-4} \text{ mol}$$

Mass of glucose = Molar mass × No. of moles = $180 \times 7.4 \times 10^{-4} = 0.1332$ g

2 Standard heat of formation ΔH_f°

- The heat change accompanying the formation of the compound from its pure constituent elements is called Heat of formation ΔH_f
- If the constituent elements are in their standard state, which is the most stable state of matter at the standard conditions, therefore the heat change which accompanies the formation of the compound is called **standard heat of formation ΔH_f°** *which is the quantity of released or absorbed heat when one mole of a compound is formed from its constituent elements where these elements are in their standard conditions.*

Applications

1 **Graphite is considered the standard state of carbon.**
Because it represents the most stable state of carbon at the standard conditions.

2 **Standard heat of formation of glucose.**

$$6C_{(s)} + 6H_{2(g)} + 3O_{2(g)} \longrightarrow C_6H_{12}O_{6(s)} \qquad \Delta H_f^\circ = -1260 \text{ kJ/mol}$$

What is meant by

The standard heat of formation of glucose equals – 1260 kJ/mol ?
This means that the quantity of released heat when one mole of glucose is formed from its constituent elements at standard conditions equals 1260 kJ

* The heat of formation of any element is supposed to be zero in the standard conditions.

Calculation of the change in heat content (the enthalpy) ΔH of the reactions in terms of the standard heat of formation ΔH_f°

∵ The change in heat content = Heat content of the products – Heat content of the reactants

∵ The standard heat of formation of a compound equals its heat content.

$$\therefore \Delta H = \left[\text{The sum of the heat of formation of the products}\right] - \left[\text{The sum of the heat of formation of the reactants}\right]$$

* **If the reaction is :** $A + B \longrightarrow C + D$

So, $\Delta H = [\Delta H^\circ_{f(C)} + \Delta H^\circ_{f(D)}] - [\Delta H^\circ_{f(A)} + \Delta H^\circ_{f(B)}]$

Examples

1 Calculate the change in the heat content of the following reaction :

$H_2S_{(g)} + 4F_{2(g)} \longrightarrow 2HF_{(g)} + SF_{6(g)}$

By using the values of the standard heat of formation ΔH_f° shown in the opposite table.

The compound	The standard heat of formation ΔH_f° (kJ/mol)
$H_2S_{(g)}$	–21
$HF_{(g)}$	–273
$SF_{6(g)}$	–1220

Solution

$\Delta H = [2\Delta H^\circ_{f(HF)} + \Delta H^\circ_{f(SF_6)}] - [\Delta H^\circ_{f(H_2S)} + 4\Delta H^\circ_{f(F_2)}]$

$= [(2 \times -273) + (-1220)\ ] - [-21 + (4 \times 0)] = (-1766) - (-21) = -1745$ kJ

2 Calculate the standard heat of formation of ammonia gas from the following equation :

$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$ $\quad \Delta H = -92.4$ kJ

Solution

$\Delta H = [2\Delta H^\circ_{f(NH_3)}] - [\Delta H^\circ_{f(N_2)} + 3\Delta H^\circ_{f(H_2)}]$

$-92.4 = 2\Delta H^\circ_{f(NH_3)} - [0 + (3 \times 0)]$

$\therefore \Delta H^\circ_{f(NH_3)} = \frac{-92.4}{2} = -46.2$ kJ/mol

Another solution

$2NH_3 \longrightarrow \Delta H_f$

2 mol $\quad$ –92.4 kJ

1 mol $\quad$? kJ/mol

$\therefore \Delta H^\circ_{f(NH_3)} = \frac{-92.4}{2} = -46.2$ kJ/mol

Note

Change in heat content ΔH **equals** the standard heat of combustion ΔH_c° when 1 mol of substance is completely combusted under the standard conditions

3 **Calculate the change in the standard enthalpy of methane combustion ΔH°_c according to the following reaction :**

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(\ell)}$$

By using the values of the standard heat of formation ΔH°_f shown in the opposite table.

The compound	The standard heat of formation ΔH°_f (kJ/mol)
$CH_{4(g)}$	–74.6
$CO_{2(g)}$	–393.5
$H_2O_{(\ell)}$	–285.85

Solution

$$\Delta H = \left[\begin{array}{c}\text{The sum of the heat of formation}\\ \text{of the products}\end{array}\right] - \left[\begin{array}{c}\text{The sum of the heat of formation}\\ \text{of the reactants}\end{array}\right]$$

$$\Delta H^\circ_c = \left[\Delta H^\circ_{f(CO_2)} + 2\Delta H^\circ_{f(H_2O)}\right] - \left[\Delta H^\circ_{f(CH_4)} + 2\Delta H^\circ_{f(O_2)}\right]$$

$$= [(-393.5) + (2 \times -285.85)] - [-74.6 + (2 \times 0)]$$

$$= [-965.2] - [-74.6] = -890.6 \text{ kJ/mol}$$

Notes

* The standard heat of combustion of hydrogen $\Delta H^\circ_{c(H_2)}$
  = The standard heat of formation of water $\Delta H^\circ_{f(H_2O)}$

  $H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(v)}$ $\qquad \Delta H^\circ_{c(H_2)} = \Delta H^\circ_{f(H_2O)}$

* The standard heat of combustion of carbon $\Delta H^\circ_{c(C)}$
  = The standard heat of formation of carbon dioxide $\Delta H^\circ_{f(CO_2)}$

  $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\qquad \Delta H^\circ_{c(C)} = \Delta H^\circ_{f(CO_2)}$

4 **The following equation represents the formation of butane gas from its constituent elements :**

$$4C_{(s)} + 5H_{2(g)} \longrightarrow C_4H_{10(g)}$$

Calculate ΔH°_f of butane, using the values of the standard heat of combustion ΔH°_c which are shown in the table.

Substance	Standard heat of combustion ΔH°_c (kJ/mol)
$C_{(s)}$	–394
$H_{2(g)}$	–286
$C_4H_{10(g)}$	–2877

Solution

The equation of the combustion of one mole of butane gas is first written :

$$C_4H_{10(g)} + \frac{13}{2} O_{2(g)} \longrightarrow 4CO_{2(g)} + 5H_2O_{(\ell)} \qquad \Delta H^\circ_c = -2877 \text{ kJ/mol}$$

$\because \Delta H^\circ_{f(CO_2)} = \Delta H^\circ_{c(C)} = -394$ kJ/mol

$\because \Delta H^\circ_{f(H_2O)} = \Delta H^\circ_{c(H_2)} = -286$ kJ/mol

$\therefore \Delta H^\circ_c = [4\Delta H^\circ_{f(CO_2)} + 5\Delta H^\circ_{f(H_2O)}] - [\Delta H^\circ_{f(C_4H_{10})} + \frac{13}{2}\Delta H^\circ_{f(O_2)}]$

$-2877 = [(4 \times -394) + (5 \times -286)] - [\Delta H^\circ_{f(C_4H_{10})} + (\frac{13}{2} \times 0)]$

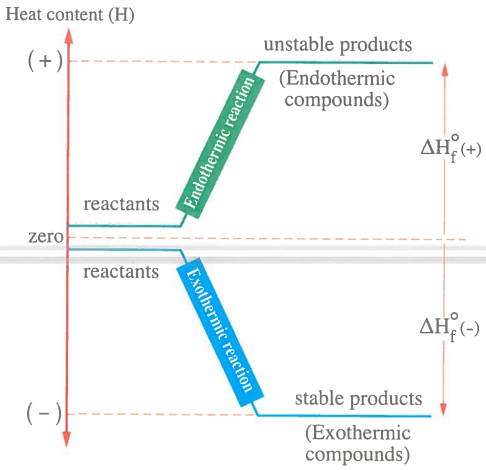
$-2877 = -3006 - \Delta H^\circ_{f(C_4H_{10})}$

$\therefore \Delta H^\circ_{f(C_4H_{10})} = (-3006) - (-2877) =$ **−129 kJ/mol**

Relation between heat of formation and the stability of the compound

- The degree of thermal stability of the compounds differs with respect to the values of their standard heat of formation, **as follows :**

The thermally stable compounds	**The thermally unstable compounds**
These compounds are	
Thermally stable at room temperature and don't tend to dissociate to their constituent elements	Thermally unstable at room temperature and tend to dissociate spontaneously to their constituent elements
Their heat of formation	
Has a negative sign ($-\Delta H^\circ_f$)	Has a positive sign ($+\Delta H^\circ_f$)
Because	
Their heat content is lower than the heat content of their constituent elements	Their heat content is higher than the heat content of their constituent elements



What is meant by

1 The formation of 1 mol of HBr at standard conditions causes releasing 36 kJ of heat ?

This means that

The standard heat of formation (ΔH_f°) of HBr is –36 kJ/mol and it is a thermally **stable** compound.

2 The formation of 1 mol of HI at standard conditions needs absorbing 26 kJ of heat ?

This means that

The standard heat of formation (ΔH_f°) of HI is +26 kJ/mol and it is a thermally **unstable** compound.

Notes

* By **decreasing** of the value of the standard heat of formation of the compound, its thermal stability **increases** and vice versa.
* Most of the reactions tend to proceed in the direction of the formation of the compounds with **lower** value of heat of formation (higher stability).

Examples

1 Arrange the compounds illustrated in the table in a descending order according to their thermal stability.

The compound	ΔH_f° (kJ/mol)
$HBr_{(g)}$	–36
$HI_{(g)}$	+26
$HF_{(g)}$	–271
$HCl_{(g)}$	–92

Idea of solution

By the decreasing of the value of the heat of formation of the compound, its thermal stability increases.

Solution

$HF_{(g)} > HCl_{(g)} > HBr_{(g)} > HI_{(g)}$

2 Which of the following equations expresses the chemical reaction that actually happens ? Giving reason.

① $2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$

② $2SO_{3(g)} \longrightarrow 2SO_{2(g)} + O_{2(g)}$

Knowing that ,

heat of formation of SO_2 gas is –296.83 kJ/mol and that of SO_3 gas is –395.72 kJ/mol

Solution

Equation ① expresses the reaction that will take place /

Because reactions proceed in the direction of the formation of the more stable compounds (lower value of heat of formation).

Hess's law

- Scientists usually prefer to use indirect methods to calculate heat of reactions. **This is due to many reasons such as :**
  1. Admixture of reactants or products with other substances.
  2. Some reactions occur very slowly and need a long time like the formation of iron rust.
  3. Being dangerous to measure the heat of some reactions experimentally.
  4. Difficulties of measuring the heat of reaction in normal conditions of pressure and temperature.

It is difficult to measure the heat of iron rusting reaction by a direct method

- In order to calculate the heat changes in these kinds of reactions, Hess proposed a law which is known as **Hess's law of constant heat summation** and it states that *the heat of reaction is a constant amount in standard conditions, whether the reaction took place in one step or a number of steps.*
- Hess's law is one of the forms of the first law of thermodynamics, because it considers the chemical reaction as an isolated system whose heat is a constant amount.
- Hess's law is dealing with the chemical equations as if they were algebraic equations which can be added together or subtracted from each other, and their coefficients can be multiplied by constant numerical values.
- **The mathematical relation of Hess's law is :** $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 + \cdots\cdots$

Application

The calculation of the heat content of a reaction : $A + 3B \longrightarrow 2D$ $\quad \Delta H = ?$

- which occurs in two steps :

$* A + 2B \xrightarrow{\text{Step (1)}} C \qquad \Delta H_1 (+)$

$* C + B \xrightarrow{\text{Step (2)}} 2D \qquad \Delta H_2 (+)$

- By adding the two equations and removing the substances that don't change during the reaction :

$A + 2B + \cancel{C} + B \longrightarrow \cancel{C} + 2D$

$A + 3B \longrightarrow 2D \qquad \Delta H = \Delta H_1 + \Delta H_2$

Example

Calculate the heat of formation of carbon monoxide gas according to the following equation : $C_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{(g)}$

By knowing the two thermal equations :

① $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\quad \Delta H_1 = -393.5$ kJ/mol

② $CO_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{2(g)}$ $\quad \Delta H_2 = -283.3$ kJ/mol

Solution

* **By subtracting equation ② from equation ① :**

$C_{(s)} + O_{2(g)} - CO_{(g)} - \frac{1}{2}O_{2(g)} \longrightarrow \cancel{CO_{2(g)}} - \cancel{CO_{2(g)}}$

$\Delta H = \Delta H_1 - \Delta H_2 = [-393.5 - (-283.3)]$ kJ/mol

* **By transferring $CO_{(g)}$ from the left side of the equation to the right side (with an opposite sign) :**

$C_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{(g)}$ $\quad \Delta H = -110.2$ kJ/mol

Note

It's practically impossible to accurately measure the released amount of heat from combustion of carbon to form carbon monoxide gas,

as the oxidation process of carbon doesn't stop only on the formation of carbon monoxide gas, but it continues forming carbon dioxide gas

Example

Assisted by the following thermochemical equations :

① $H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(\ell)}$ $\quad \Delta H_1 = -286$ kJ

② $2Na_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow Na_2O_{(s)}$ $\quad \Delta H_2 = -414$ kJ

③ $Na_{(s)} + \frac{1}{2}O_{2(g)} + \frac{1}{2}H_{2(g)} \longrightarrow NaOH_{(s)}$ $\quad \Delta H_3 = -425$ kJ

Calculate the change in the standard enthalpy of the reaction :

$$Na_2O_{(s)} + H_2O_{(\ell)} \longrightarrow 2NaOH_{(s)}$$

Solution

* **By reversing the direction of equation ② :**

$Na_2O_{(s)} \longrightarrow 2Na_{(s)} + \frac{1}{2}O_{2(g)}$ $\quad \Delta H_4 = +414$ kJ ④

* **By multiplying equation ③ × 2 :**

$2Na_{(s)} + O_{2(g)} + H_{2(g)} \longrightarrow 2NaOH_{(s)}$ $\quad \Delta H_5 = 2 \times (-425) = -850$ kJ ⑤

* **By adding the equations ④ , ⑤ and subtracting equation ① :**

$$Na_2O_{(s)} + \cancel{2Na_{(s)}} + \cancel{O_{2(g)}} + \cancel{H_{2(g)}} - \cancel{H_{2(g)}} - \cancel{\frac{1}{2}O_{2(g)}} \longrightarrow$$

$$\cancel{2Na_{(s)}} + \cancel{\frac{1}{2}O_{2(g)}} + 2NaOH_{(s)} - H_2O_{(\ell)}$$

$$\Delta H = \Delta H_4 + \Delta H_5 - \Delta H_1 = [(414) + (-850) - (-286)] \text{ kJ}$$

* **And by transferring $H_2O_{(\ell)}$ from the right side of the equation to the left side of the equation (with an opposite sign) :**

$Na_2O_{(s)} + H_2O_{(\ell)} \longrightarrow 2NaOH_{(s)}$ $\quad \Delta H = -150$ kJ

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Choose the correct answer :

(1) Examples of heat changes that accompany the chemical reactions are heat of .....

a. combustion. b. formation. c. solution. d. a. and b.

(2) The heat of formation of one mole of HF in the following reaction is .....

$$H_{2(g)} + F_{2(g)} \longrightarrow 2HF_{(g)} \ , \ \Delta H = -534.7 \text{ kJ}$$

a. –178.2 kJ/mol b. –267.35 kJ/mol

c. –534.7 kJ/mol d. –1069.4 kJ/mol

(3) The heat of the reaction ..... by increasing the number of steps of the reaction under the standard conditions.

a. increases b. decreases c. is doubled d. is constant

(4) The most unstable compounds .....

a. have a positive value of heat of formation.

b. their heat contents are less than those of their elements.

c. have a negative value of heat of formation.

d. are difficult to dissociate into elements.

(5) The stability of the compound ..... by increasing its heat content.

a. increases b. decreases c. doesn't change d. disappears

(6) Most reactions proceed in the direction of the formation of .....

a. endothermic compounds. b. less stable compounds.

c. more stable compounds. d. compounds with higher heat content.

2 Choose from column (B) the suitable thermochemical equation for column (A) :

(A)	(B)	
(1) Heat of combustion	(1) $Al_{(s)} + \frac{3}{2}Cl_{2(g)} \longrightarrow AlCl_{3(s)}$	$\Delta H = +704$ kJ
(2) Heat of formation	(2) $NH_4NO_{3(s)} + H_2O_{(\ell)} \longrightarrow NH_4NO_{3(aq)}$	$\Delta H = +25.7$ kJ
(3) Heat of dilution	(3) $HCl_{(conc)} + nH_2O_{(\ell)} \longrightarrow HCl_{(dil)}$	$\Delta H = -45.61$ kJ
(4) Heat of solution	(4) $Li^+_{(g)} + F^-_{(g)} \longrightarrow LiF_{(s)}$	$\Delta H = -1047$ kJ
	(5) $SO_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow SO_{3(g)}$	$\Delta H = -99$ kJ

Steady

Open book questions

Answered

Multiple choice questions

1 Which of the following equations represents a combustion reaction ? .....

(a) $C_2H_4 + H_2O \longrightarrow C_2H_5OH$

(b) $C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$

(c) $CH_3COOH + 2O_2 \longrightarrow 2CO_2 + 2H_2O$

(d) $CH_3COOH + CH_3OH \longrightarrow CH_3COOCH_3 + H_2O$

Questions marked by this mark are for the superiors and their ideas are explained in the answers

2 What is the hydrocarbon which when burnt (combusts), it yields equal numbers of moles of both carbon dioxide and water vapour ? .....

(a) C_2H_6 (b) C_3H_8

(c) C_4H_8 (d) C_5H_{12}

3 If the heat of combustion of graphite is –393.5 kJ/mol, so the heat of combustion of 120 g of graphite is ..... [C = 12]

(a) –3.935 kJ (b) –39.35 kJ (c) –393.5 kJ (d) –3935 kJ

4 In the equation : $\frac{1}{2}S_{8(s)} + 6O_{2(g)} \longrightarrow 4SO_{3(g)}$ $\Delta H = -1590$ kJ

What is the standard heat of combustion of sulphur ? .....

(a) –1590 kJ/mol (b) –3180 kJ/mol

(c) +1590 kJ/mol (d) –795 kJ/mol

5 According to the opposite table.. What is the fuel which produces higher amount of thermal energy when 1 g of it combusts completely ? .....

(a) CH_4

(b) C_2H_5OH

(c) C_3H_8

(d) C_7H_{16}

Fuel	Chemical formula	Molar mass (g/mol)	Heat of combustion (kJ/mol)
Methane	CH_4	16	–880
Ethanol	C_2H_5OH	46	–1380
Propane	C_3H_8	44	–2200
Heptane	C_7H_{16}	100	–4800

6 The opposite table represents the heat of combustion of four hydrocarbons..
What is the formula of the hydrocarbon (X) which belongs to the same series of the illustrated hydrocarbons and its heat of combustion equals –6125 kJ/mol ? .....

Hydrocarbon	Heat of combustion (kJ/mol)
C_3H_8	–2219
C_4H_{10}	–2878
C_5H_{12}	–3535
C_6H_{14}	–4163

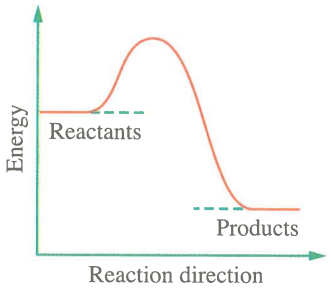
(a) C_7H_{16} (b) C_8H_{18}
(c) C_9H_{20} (d) $C_{10}H_{22}$

7 Which of the following choices represents the probable signs of each of the heat of solution, the heat of combustion and the heat of formation ? .....

Choices	Heat of solution	Heat of combustion	Heat of formation
(a)	+ , –	– only	+ , –
(b)	+ , –	+ , –	+ , –
(c)	+ only	+ only	+ only
(d)	– only	+ only	– only

8 The released heat from the reaction :
$CO_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{2(g)}$ $\Delta H = -283.3$ kJ/mol is the heat of .....
(a) formation of CO_2 (b) combustion of CO
(c) formation of CO (d) combustion of CO_2

9 The opposite graphical figure can not represent the change in the standard enthalpy of .....
(a) combustion.
(b) formation.
(c) attachment of the molecules of solvent to solute.
(d) evaporation.



10 Which of the following equations represents the standard heat of formation ? .....
(a) $C_{(g)} + O_{2(g)} \longrightarrow CO_{2(g)}$ (b) $C_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{(g)}$
(c) $2N_{(g)} + 4O_{(g)} \longrightarrow N_2O_{4(g)}$ (d) $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$

11 In which reaction the change in heat content is equal to the standard heat of formation ? .....
(a) $2Ca_{(s)} + O_{2(g)} \longrightarrow 2CaO_{(s)}$ (b) $2C_{(s)} + 2O_{2(g)} \longrightarrow 2CO_{2(g)}$
(c) $3Mg_{(s)} + N_{2(g)} \longrightarrow Mg_3N_{2(s)}$ (d) $C_2H_{2(g)} + H_{2(g)} \longrightarrow C_2H_{4(g)}$

12 In the reaction :

$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(v)}$ $\Delta H = X$ kJ/mol

Which of the following choices shows both the type of change in enthalpy, and the sign of ΔH of this reaction ? .....

Choices	Type of change in enthalpy	Sign of ΔH
(a)	Formation only	Positive
(b)	Formation only	Negative
(c)	Combustion and formation	Positive
(d)	Combustion and formation	Negative

13 If the standard heat of formation of NO compound equals +90 kJ/mol, What is the value of ΔH of the reaction : $2NO_{(g)} \longrightarrow N_{2(g)} + O_{2(g)}$? .....

(a) –180 kJ (b) –90 kJ (c) +90 kJ (d) +180 kJ

14 In terms of the reaction : $4Fe_{(s)} + 3O_{2(g)} \longrightarrow 2Fe_2O_{3(s)}$ $\Delta H = -1648$ kJ

What is the standard heat of formation of Fe_2O_3 ? .....

(a) Zero (b) –824 kJ/mol

(c) –1648 kJ/mol (d) –3296 kJ/mol

15 Pb_3O_4 is prepared by heating PbO in air according to the equation : $6PbO_{(s)} + O_{2(g)} \longrightarrow 2Pb_3O_{4(s)}$

What data should be provided to calculate the change in enthalpy of the previous reaction ? .....

(a) Heat of combustion of Pb and heat of formation of Pb_3O_4

(b) Heat of combustion of PbO and heat of formation of Pb_3O_4

(c) Heat of formation of PbO and heat of breaking bonds in O_2

(d) Heat of formation of PbO and heat of formation of Pb_3O_4

16 Hydrogen peroxide decomposes according to the equation : $2H_2O_{2(\ell)} \longrightarrow 2H_2O_{(\ell)} + O_{2(g)}$

In terms of the opposite table..

What is the change in the enthalpy of the decomposition of hydrogen peroxide ? .....

Substance	Standard heat of formation (kJ/mol)
$H_2O_{2(\ell)}$	–187.8
$H_2O_{(\ell)}$	–285.8

(a) –98 kJ (b) –196 kJ

(c) –398 kJ (d) –451 kJ

17 Anhydrous copper (II) chloride combines with water forming hydrated copper (II) chloride, according to the equation :

$$CuCl_{2(s)} + 2H_2O_{(\ell)} \longrightarrow CuCl_2.2H_2O_{(aq)}$$

What is the value of the change in the heat content of this reaction in terms of ΔH_f° of the compounds shown in the opposite table ? .....

Substance	ΔH_f° (kJ/mol)
$H_2O_{(\ell)}$	–286
$CuCl_{2(s)}$	–206
$CuCl_2.2H_2O_{(aq)}$	–808

(a) –1586 kJ/mol (b) –316 kJ/mol (c) –110 kJ/mol (d) –30 kJ/mol

18 Bicarbonate ion HCO_3^- reacts with positive hydrogen ion H^+ according to the equation : $HCO^-_{3(aq)} + H^+_{(aq)} \longrightarrow H_2O_{(\ell)} + CO_{2(g)}$ $\Delta H = +12.7$ kJ/mol

In terms of the opposite table..
What is the standard heat of formation of $H^+_{(aq)}$ ion ? .....

Substance	Standard heat of formation (kJ/mol)
$H_2O_{(\ell)}$	–285.8
$CO_{2(g)}$	–393.5
$HCO^-_{3(aq)}$	–692

(a) –25.4 kJ/mol (b) Zero
(c) +25.4 kJ/mol (d) +1384 kJ/mol

19 In terms of the following information :

- Standard heat of combustion of carbon C = –394 kJ/mol
- Standard heat of formation of water H_2O = –286 kJ/mol
- Standard heat of formation of methanol CH_3OH = –239 kJ/mol

Which of the following is the standard heat of combustion of methanol ? .....

(a) –441 kJ/mol (b) –727 kJ/mol
(c) –919 kJ/mol (d) –1205 kJ/mol

20 If the heat of formation of HCl equals –92.3 kJ/mol and the heat of formation of HI is +25.9 kJ/mol, so .....

(a) HCl is less stable. (b) HI has a higher heat content.
(c) HCl is easily decomposed by heat. (d) HI is difficult to be decomposed by heat.

21 The released energy increases during the formation of a compound, as the ..... of the compound increases.

(a) weight (b) mass
(c) stability (d) decomposition

22 In the two following equations :

- $I_{2(g)} + 3Cl_{2(g)} \longrightarrow 2ICl_{3(s)}$ $\quad \Delta H_f^\circ = -214$ kJ
- $I_{2(s)} \longrightarrow I_{2(g)}$ $\quad \Delta H_f^\circ = +38$ kJ/mol

What is the value of the standard heat of formation of iodine trichloride $ICl_{3(s)}$? .....

(a) +176 kJ/mol (b) –88 kJ/mol

(c) – 176 kJ/mol (d) – 214 kJ/mol

23 "Sublimation means the change of a substance from the solid state directly to the gaseous state without becoming a liquid".

By the indication of the following equations :

- $H_2O_{(\ell)} \longrightarrow H_2O_{(v)}$ $\quad \Delta H = +43.7$ kJ/mol
- $H_2O_{(s)} \longrightarrow H_2O_{(\ell)}$ $\quad \Delta H = +6.05$ kJ/mol

What is the value of ΔH of the sublimation of ice ? .....

(a) +49.75 kJ/mol (b) +37.65 kJ/mol

(c) +43.7 kJ/mol (d) –43.7 kJ/mol

24 From the following thermochemical equations :

- $2Cr_{(s)} + \frac{3}{2}O_{2(g)} \longrightarrow Cr_2O_{3(s)}$ $\quad \Delta H = -1130$ kJ/mol
- $C_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{(g)}$ $\quad \Delta H = -110$ kJ/mol

What is the value of ΔH of the reaction :

$3C_{(s)} + Cr_2O_{3(s)} \longrightarrow 2Cr_{(s)} + 3CO_{(g)}$? .....

(a) –800 kJ (b) +800 kJ

(c) –1460 kJ (d) +1460 kJ

25 If the molar enthalpy of formation of HCl gas equals –92.3 kJ/mol, and the standard heat of solution of this gas in water equals –75.14 kJ/mol,

What is the value of the enthalpy of formation of each of $H^+_{(aq)}$ and $Cl^-_{(aq)}$? .....

(a) –17.16 kJ/mol (b) –167.44 kJ/mol

(c) +17.16 kJ/mol (d) +167.44 kJ/mol

26 In the three following equations :

(1) $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(\ell)}$ ΔH_1

(2) $4NH_{3(g)} + 3O_{2(g)} \longrightarrow 6H_2O_{(\ell)} + 2N_{2(g)}$ ΔH_2

(3) $4NH_{3(g)} \longrightarrow 6H_{2(g)} + 2N_{2(g)}$ ΔH_3

What is the value of ΔH_3 of reaction (3) ? .....

(a) $\Delta H_3 = \Delta H_2 - \frac{\Delta H_1}{2}$ (b) $\Delta H_3 = \frac{\Delta H_2}{2} - 3\Delta H_1$

(c) $\Delta H_3 = \Delta H_2 - \Delta H_1$ (d) $\Delta H_3 = \Delta H_2 - 3\Delta H_1$

27 According to the three following equations :

(1) $S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$ $\Delta H = -297$ kJ/mol

(2) $S_{(s)} + \frac{3}{2}O_{2(g)} \longrightarrow SO_{3(g)}$ $\Delta H = -395$ kJ/mol

(3) $2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$ $\Delta H = ?$

What is the value of ΔH of reaction (3) ? .....

(a) –196 kJ (b) –98 kJ (c) +98 kJ (d) +196 kJ

Essay questions

28 **Calculate the standard heat of combustion** of methane CH_4, where the change in heat content accompanying the combustion of 8 g of methane in an excess amount of oxygen is –482.55 kJ [C = 12 , H = 1]

29 Methane gas combusts according to the following equation :

$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(\ell)}$ $\Delta H^\circ_c = -890$ kJ/mol

Calculate the quantity of heat which results from the combustion of : [C = 12 , H = 1]

(1) 5.76 g of methane gas in excess of oxygen gas.

(2) 500 mL of methane gas (at STP) in excess of oxygen gas.

30 **Propanol liquid C_3H_8O combusts in an exothermic reaction, and its standard heat of combustion $\Delta H^\circ_c = -2017$ kJ/mol**

(1) Write the thermochemical equation which represents propanol combustion.

(2) Calculate the mass of propanol which is required to combust completely in excess of oxygen gas to yield a quantity of heat equals 1×10^4 kJ

"Knowing that the molar mass of propanol = 60 g/mol".

31 **If you know that** ΔH_c° of propane C_3H_8 equals –2323.7 kJ/mol
Calculate the mass of propane required to combust completely to heat 500 g of pure water from 20°C to the boiling point (assuming no heat loss). [C = 12 , H = 1]

32 **Heat produced from heating hexane was used in heating a known mass of water, the results were recorded in the opposite table :**

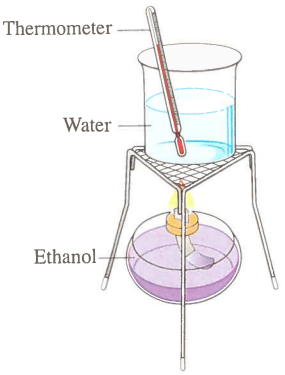
Mass of combusted hexane	0.32 g
Mass of water	50 g
Initial temperature of water	22°C
Final temperature of water	68°C

(1) Calculate the quantity of heat produced from combusting hexane in this experiment in Joule.

(2) Calculate the change in enthalpy of combustion of hexane, knowing that its molar mass is 86 g/mol

(3) Suggest two possibilities that may result in the difference between the two values of enthalpy of combustion of hexane, the calculated value and the actual value.

33 **The illustrated experiment in the opposite figure shows** the process of heating 100 g of water using the thermal energy resulted from burning 1.8 g of ethanol C_2H_5OH according to the equation :



$$C_2H_5OH_{(\ell)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(\ell)}$$

Calculate the percentage of lost energy (to the surroundings and the metal container), knowing that the temperature of water has rised from 25°C to 40°C, and the heat of combustion of ethanol equals –1364 kJ/mol

[C = 12 , H = 1 , O = 16]

34 **In the following reaction :**

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)} \qquad \Delta H = -92 \text{ kJ}$$

[N = 14 , H = 1]

(1) Calculate :

1- Standard heat of formation of ammonia gas.

2- The change in heat content accompanied to formation of 30 g of ammonia gas.

(2) Draw the energy diagram of this reaction.

35 **Calculate the heat of formation of water, assisted by the following equation :**

$$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(\ell)} \qquad \Delta H^\circ = -285.8 \text{ kJ/mol}$$

Then calculate the quantity of heat released from the formation of 54 g of H_2O

[H = 1 , O = 16]

36 **Hydrogen gas is used as a fuel in space ships, according to the following equation :**

$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$ $\quad \Delta H_c = -484$ kJ

Calculate :

(1) The standard heat of combustion of hydrogen.

(2) The heat of the complete combustion of 1 g of H_2 gas.

(3) The standard heat of formation of water vapour. [H = 1]

37 Ethane gas C_2H_6 burns according to the following equation :

$2C_2H_{6(g)} + 7O_{2(g)} \longrightarrow 4CO_{2(g)} + 6H_2O_{(\ell)}$

Calculate the change in molar enthalpy of combustion of ethane, knowing that :

ΔH_c° of carbon (C) = –393.5 kJ/mol

ΔH_c° of hydrogen (H) = –285.85 kJ/mol

ΔH_f° of ethane (C_2H_6) = –140 kJ/mol

38 **Arrange the compounds in each table ascendingly according to their thermal stability :**

①	Compound	ΔH_f° (kJ/mol)
(1)	A	–200
(2)	B	+400
(3)	C	–400
(4)	D	+200

②	Compound	ΔH_f° (kJ/mol)
(1)	$PbO_{2(s)}$	–277.4
(2)	$PbSO_{4(s)}$	–919.94
(3)	$PbBr_{2(s)}$	–278.7
(4)	$PbBr_{2(aq)}$	–244.8

③	Compound	ΔH_f° (kJ/mol)
(1)	$CH_{4(g)}$	–74.81
(2)	$C_2H_{2(g)}$	+226.73
(3)	$C_2H_{4(g)}$	+52.26
(4)	$C_4H_{10(g)}$	–126.15

39 **Which of the following two equations** represents the actual reaction ? **Give reason :**

(1) $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$

(2) $2NO_{2(g)} \longrightarrow 2NO_{(g)} + O_{2(g)}$

Knowing that the heat of formation of each of NO and NO_2 are +90.25 kJ/mol and –33.2 kJ/mol respectively.

40 **In terms of Hess's law.. Calculate the standard heat of formation of** hydrogen peroxide H_2O_2 by the indication of the following equations :

① $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(\ell)}$ $\quad \Delta H_1 = -570$ kJ

② $H_2O_{(\ell)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{2(\ell)}$ $\quad \Delta H_2 = +33.4$ kJ

41 **According to Hess's law.. Calculate ΔH for the reaction :**

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

By using the following thermochemical equations :

① $S_{(s)} + \frac{3}{2}O_{2(g)} \longrightarrow SO_{3(g)}$ $\quad \Delta H_1 = -395.72$ kJ

② $2SO_{3(g)} \longrightarrow 2SO_{2(g)} + O_{2(g)}$ $\quad \Delta H_2 = -296.83$ kJ

42 **Calculate the standard heat of formation of acetylene C_2H_2 from its elements :**

$$2C_{(s)} + H_{2(g)} \longrightarrow C_2H_{2(g)}$$

By knowing the following thermochemical equations :

① $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\quad \Delta H_1 = -394$ kJ/mol

② $H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(v)}$ $\quad \Delta H_2 = -286$ kJ/mol

③ $C_2H_{2(g)} + \frac{5}{2}O_{2(g)} \longrightarrow 2CO_{2(g)} + H_2O_{(v)}$ $\quad \Delta H_3 = -1300$ kJ/mol

New types of questions ?

Answered

Choosing two out of five choices questions :

1 The value of $\Delta H°$ represents each of the change in the standard enthalpy of combustion and the change in the standard enthalpy of formation of the two equations .....

(a) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

(b) $2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)}$

(c) $CO_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{2(g)}$

(d) $C_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{(g)}$

(e) $\frac{1}{2}N_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow NO_{(g)}$

2 ΔH_f° does not equal zero for each of .....

(a) $Br_{2(\ell)}$ (b) $Fe_{(s)}$ (c) $I_{2(s)}$

(d) $O_{3(g)}$ (e) $Na^+_{(g)}$

3 When a definite amount of magnesium combusted in the standard conditions, 20.15 g of $MgO_{(s)}$ were formed, and the reaction was accompanied by releasing a quantity of heat equals 300.9 kJ,
What are the two choices which represent the standard heat of formation of $MgO_{(s)}$?.....

[Mg = 24 , O = 16]

(a) −300.9 kJ/mol

(b) −597.32 kJ/mol

(c) $+3009 \times 10^2$ J/mol

(d) −142.9 kcal/mol

(e) +59.32 kcal/mol

4 To calculate the change in the heat content for the reaction :

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(v)}$$

This requires to know .....

(a) the heat of formation of $CO_{2(g)}$ and $H_2O_{(v)}$ only.

(b) the heat of formation of $C_3H_{8(g)}$ and $O_{2(g)}$ only.

(c) the heat of formation of $C_3H_{8(g)}$, $CO_{2(g)}$ and $H_2O_{(v)}$ only.

(d) the heat contents of the products and those of the reactants only.

(e) the heat of formation of $C_3H_{8(g)}$, $O_{2(g)}$, $CO_{2(g)}$ and $H_2O_{(v)}$

5 Based on the data in the following table :

Compound	CO	NO_2	SO_2	C_2H_2	H_2S
ΔH_f° (kJ/mol)	−110.5	+33.9	−300.4	+226.73	+90.4

What are the two compounds whose formation reactions are more endothermic ? .....

(a) CO (b) NO_2 (c) SO_2

(d) C_2H_2 (e) H_2S

General Exercises ON UNIT 4

Answered

Multiple choice questions

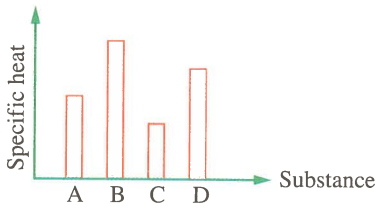
1 When a piece of copper its temperature equals 150°C is thrown in boiling water, heat transfers from copper to water due to the.....

(a) higher thermal energy of water.
(b) higher temperature of copper than water.
(c) higher thermal energy of copper.
(d) higher temperature of water than copper.

2 Which of the following affects the specific heat of the substance ? .....

(a) Its volume.
(b) Quantity of heat lost or gained.
(c) Its mass.
(d) Its physical state.

3 The opposite graphical figure represents the specific heat of the solid substances A, B, C and D which are all equal in mass and at the standard temperature.. Which of these substances takes less time to reach 70°C ? .....



(a) A
(b) B
(c) C
(d) D

4 The opposite table shows the values of the specific heat of four substances at room temperature.. Which of these substances takes the least possible time to reach 80°C ? .....

Substance	Specific heat (J/g°C)
A	0.385
B	0.444
C	0.711
D	0.889

(a) A
(b) B
(c) C
(d) D

5 200 g ball of copper is heated by acquiring a quantity of heat equals 4928 J until its temperature becomes 80°C, if the specific heat of copper is 0.385 J/g°C, so What is the initial temperature ? .....

(a) 16°C
(b) 64°C
(c) 80°C
(d) 100°C

6 Which of the following is used to measure the heat of combustion of a certain fuel ? .....

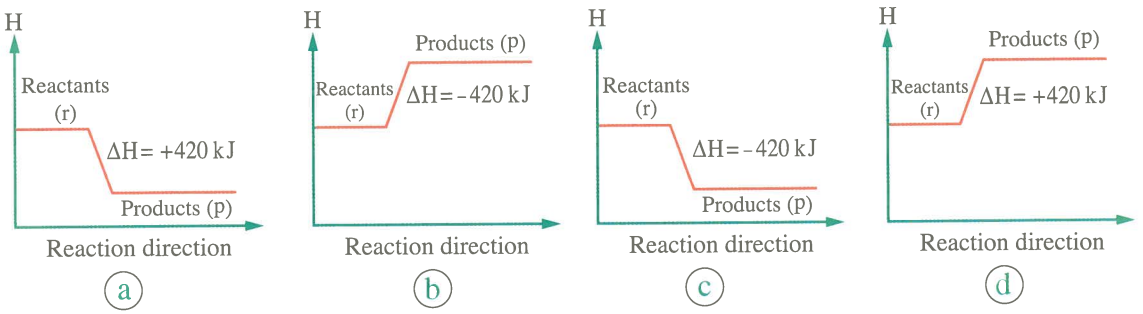
(a) Internal combustion engine.
(b) Thermometer.
(c) Bomb calorimeter.
(d) Coffee cup calorimeter.

7 It is concluded from the equation : $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$ $\Delta H = -92$ kJ that the molar enthalpy of ammonia equals .....

(a) –46 kJ/mol
(b) +46 kJ/mol
(c) –92 kJ/mol
(d) +92 kJ/mol

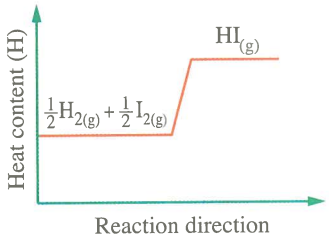
8 The decomposition reaction of iron (II) sulphate is represented by the following thermochemical equation : $2FeSO_{4(s)} + 420\ kJ \longrightarrow Fe_2O_3 + SO_{2(g)} + SO_{3(g)}$

Which of the following energy diagrams represents this reaction ? .....



9 The opposite diagram represents the reaction of formation of HI gas from its constituent elements..

Which of the following represents the change in heat which accompanies this reaction ? .....



(a) H of reactants is higher than H of products, and the sign of ΔH is positive.

(b) H of products is lower than H of reactants, and the sign of ΔH is negative.

(c) H of products is higher than H of reactants, and the sign of ΔH is positive.

(d) H of reactants is lower than H of products, and the sign of ΔH is negative.

10 What can we conclude from this thermochemical equation :

$$H_2O_{(l)} \rightleftharpoons H_2O_{(v)} \quad \Delta H = +44\ kJ/mol$$

We conclude that .....

(a) the heat content of water vapour is less than half the heat content of liquid water.

(b) the heat content of water vapour is equal to the heat content of liquid water.

(c) the heat content of water vapour is higher than the heat content of liquid water.

(d) the heat content of water vapour is half the heat content of liquid water.

11 Which of the following equations represents an exothermic reaction ? .....

(a) $XY_5 \longrightarrow XY_3 + Y_2 \quad \Delta H = +420\ kJ$

(b) $XY_5 \longrightarrow XY_3 + Y_2 + 420\ kJ$

(c) $XY_5 \longrightarrow XY_3 + Y_2 - 420\ kJ$

(d) $XY_5 + 420\ kJ \longrightarrow XY_3 + Y_2$

12 From the equation : $2C_{(s)} + 2H_{2(g)} + 52.3\ kJ \longrightarrow C_2H_{4(g)}$

It can be concluded that .....

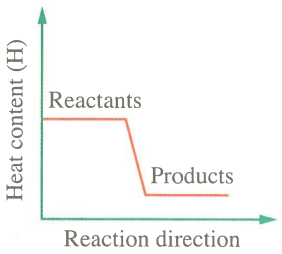
(a) the medium acquires heat.

(b) heat transfers from the surrounding to the system.

(c) the system loses heat.

(d) heat transfers from the system to the surrounding.

13 **Which of the following is correct in terms of the energy diagram illustrated in the opposite figure ?** .....



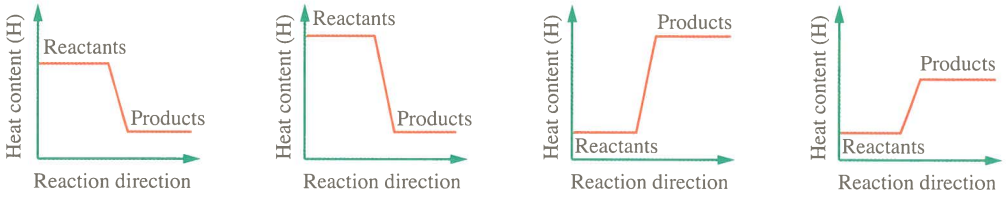
(a) The sum of heat contents of the reactants is higher than the sum of heat contents of the products.

(b) The energy required to break the bonds in the reactants equals the released energy during the formation of the products bonds.

(c) The sum of the heat contents of the products is higher than the sum of the heat contents of the reactants.

(d) The energy required to break the bonds in the reactants is higher than the released energy during the formation of the products bonds.

14 **In which of the following cases the quantity of absorbed heat is minimum ?** .....



15 **On dissolving 28 g of potassium hydroxide in water to form 1 L of the solution, the temperature rised by 6.89°C, What is the molar heat of solution of potassium hydroxide ?** ..... **[K = 39 , H = 1 , O = 16]**

(a) –57.6 kJ/mol (b) +57.6 kJ/mol (c) +28.8 kJ/mol (d) –28.8 kJ/mol

16 **On dissolving 1 mol of potassium nitrate salt in a liquid solvent to form 1 L of the solution, the temperature dropped by 4°C, so if the quantity of the absorbed energy equals 16720 J .. What is the value of the specific heat of the solvent ?** .....

(a) 10 cal/g.°C (b) 4.18 cal/g.°C

(c) 0.418 cal/g.°C (d) 1 cal/g.°C

17 **If the separation energy of ammonium nitrate salt in water equals 150 kJ, its hydration energy equals 120 kJ and the separation energy of water equals 100 kJ, Which of the following choices represents both the type of solution of this salt, and the value of its ΔH ?** .....

Choices	(a)	(b)	(c)	(d)
Type of solution	Exothermic	Endothermic	Exothermic	Endothermic
ΔH value	130 kJ	170 kJ	170 kJ	130 kJ

18 **When drops of concentrated sulphuric acid are added to water, the temperature of water rises because** .....

(a) the sum of the two separation energies of the particles of each of the solute and the solvent are higher than the hydration energy.

(b) the sum of the two separation energies of the particles of each of the solute and the solvent are lower than the hydration energy.

(c) the separation energy of ions is higher than the hydration energy.

(d) the separation energy of ions is lower than the hydration energy.

19 **In the reaction :** $HCl_{(g)} \xrightarrow{water} H^+_{(aq)} + Cl^-_{(aq)}$ $\Delta H = -83.6$ kJ/mol

Which of the following choices represents both the type of solution, and the scientific explanation for that ? .....

Choices	(a)	(b)	(c)	(d)
Type of solution	Endothermic	Exothermic	Endothermic	Exothermic
Scientific explanation	$\Delta H_3 > (\Delta H_1 + \Delta H_2)$	$\Delta H_3 < (\Delta H_1 + \Delta H_2)$	$\Delta H_3 < (\Delta H_1 + \Delta H_2)$	$\Delta H_3 > (\Delta H_1 + \Delta H_2)$

20 **Ammonium chloride dissolves in water according to the equation :**

$$NH_4Cl_{(s)} + Heat \xrightarrow{water} NH^+_{4(aq)} + Cl^-_{(aq)}$$

Which of the following statements represents the previous dissolving process ? .....

(a) Sum of the two separation energies of the molecules of each of the solvent and the solute are lower than the hydration energy.

(b) Separation energy of the solvent molecules and the hydration energy are higher than the separation energy of the solute molecules.

(c) Separation energy of the solvent molecules and the hydration energy are lower than the separation energy of the solute molecules.

(d) Sum of the two separation energies of the molecules of each of the solvent and the solute are higher than the hydration energy.

21 **The process represented by the following thermochemical equation is accompanied by change in heat :** $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)} + 4.5$ J

What is the type of this change in heat ? .....

(a) Physical change accompanies the dilution process.

(b) Physical change accompanies the dissolving process.

(c) Chemical change accompanies the dilution process.

(d) Chemical change accompanies the dissolving process.

22 In the equation : $\frac{1}{2}N_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow NO_{(g)}$ $\Delta H = +90.29$ kJ/mol

The change in heat content of the previous reaction represents the heat of .....

(a) solution. (b) combustion. (c) formation. (d) neutralization.

23 If the heat content of hydrogen bromide gas is less than the heat content of the elements forming it.. What would be the thermochemical equation which represents the standard heat of formation of hydrogen bromide gas ? .....

(a) $H_{2(g)} + Br_{2(\ell)} \longrightarrow 2HBr_{(g)}$ $\Delta H = +36.23$ kJ

(b) $\frac{1}{2}H_{2(g)} + \frac{1}{2}Br_{2(\ell)} \longrightarrow HBr_{(g)}$ $\Delta H = -36.23$ kJ

(c) $H_{2(g)} + Br_{2(\ell)} \longrightarrow 2HBr_{(g)}$ $\Delta H = -36.23$ kJ

(d) $\frac{1}{2}H_{2(g)} + \frac{1}{2}Br_{2(\ell)} \longrightarrow HBr_{(g)}$ $\Delta H = +36.23$ kJ

24 From the following equations :

* $C_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{(g)}$ $\Delta H = -110.3$ kJ/mol

* $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\Delta H = -393.5$ kJ/mol

It is concluded that .....

(a) molar enthalpy of CO_2 gas is higher than molar enthalpy of CO gas.

(b) molar enthalpy of CO_2 gas is lower than molar enthalpy of CO gas.

(c) molar enthalpy of CO_2 gas is equal to molar enthalpy of CO gas.

(d) molar enthalpies of CO and CO_2 gases equal zero.

Miscellaneous questions

25 A 100 g metallic object is placed in hot water, this object acquired a quantity of heat equals 100 cal, calculate the change in this object temperature, knowing that its specific heat equals 0.24 J/g.°C

26 A sample of one of the illustrated substances in the opposite table its mass is 5 g is heated, its temperature rised from 25.2°C to 55.1°C as a result of absorbing a quantity of heat equals 133 J

Use the relation $q_p = m\ c\ \Delta T$ to identify this substance.

Substance	Specific heat (J/g.°C)
W	0.240
X	0.889
Y	0.444
Z	0.139

27 In terms of the reaction : $Br_{2(\ell)} + H_{2(g)} \longrightarrow 2HBr_{(g)}$ $\Delta H = -72$ kJ

Illustrate with a thermochemical equation the decomposition of 1 mol of hydrogen bromide.

28 **In terms of the reaction :**

$N_2H_{4(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)} + N_{2(g)}$ $\Delta H = -577$ kJ/mol

Calculate the value of the average bond energy of (N – N) in hydrazine molecule N_2H_4, by knowing the average bond energies illustrated in the opposite table.

Bond	Average bond energy (kJ/mol)
N – H	391
O = O	495
N ≡ N	941
O – H	463

29 **Assisted by the equation and the table :**

$X_2Y_{(\ell)} \longrightarrow X_{2(g)} + \frac{1}{2} Y_{2(g)}$

Calculate ΔH of the reaction, then determine the type of change in heat content (whether endothermic or exothermic).

Bond	X – Y	Y = Y	X – X
Average bond energy (kJ/mol)	467	498	432

30 **Using the illustrated information in the opposite table, which belongs to the following reaction :**

$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$

(1) Calculate the change in heat content of the reaction.

(2) Is the reaction exothermic or endothermic ? Explain.

Bond	Average bond energy (kJ/mol)
Cl – Cl	240
H – H	432
H – Cl	430

31 **Write the thermochemical equation** which represents the formation of 2 mol of calcium oxide, knowing that its molar heat of formation equals –635.1 kJ/mol

32 **In terms of the heat of formation of the reactants and the products of the following reaction which are shown in the opposite table :**

$C_2H_{6(g)} + \frac{7}{2} O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(\ell)}$

(1) Calculate ΔH of the reaction.

(2) Is this reaction exothermic or endothermic ? Explain.

Compound	Heat of formation (kJ/mol)
$C_2H_{6(g)}$	–84.67
$CO_{2(g)}$	–393.5
$H_2O_{(\ell)}$	–286

33 **Propane gas C_3H_8 combusts forming carbon dioxide and water vapour :**

(1) Write the thermochemical equation which represents propane combustion, knowing that its standard heat of combustion equals –2220 kJ/mol

(2) Calculate the quantity of heat produced from the complete combustion of 0.44 g of propane gas.

[C = 12 , H = 1]

34 **The following equation represents the decomposition of ammonia gas to its standard constituent elements :** $2NH_{3(g)} \longrightarrow N_{2(g)} + 3H_{2(g)}$ $\Delta H = +92$ kJ

Write the thermochemical equation which represents the standard heat of formation of ammonia.

Exam model about Unit 4

Answered

Rate your level

Superior	Remarkable	above average	Weak
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	less than 10 marks

Choose the correct answer for the questions 1 : 10 ..... 10 marks

1 In the thermochemical reaction : $R_2 + Q_2 \longrightarrow 2RQ$

Which of the following choices represents the reaction which produces higher amount of heat ? .....

Choices	(a)	(b)	(c)	(d)
Bond in R_2	Strong	Strong	Weak	Weak
Bond in Q_2	Strong	Strong	Weak	Weak
Bond in RQ	Strong	Weak	Strong	Weak

2 The isolated system .....

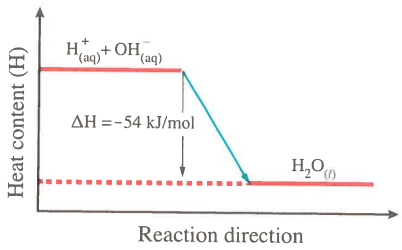
(a) has boundaries that allow the exchange of matter but not heat.

(b) has boundaries that allow the exchange of heat but not matter.

(c) has boundaries that allow the exchange of neither heat nor matter.

(d) has boundaries that allow the exchange of both heat and matter.

3 The reaction of hydrochloric acid with sodium hydroxide solution is represented by the opposite energy diagram.. What is the amount of released heat when 0.1 mol of each of the acid and the base react together ? .....



(a) 0.54 kJ (b) 2.7 kJ

(c) 5.4 kJ (d) 0.8 kJ

4 334 J of heat are required to convert 1 g of ice to 1 g of water at 0°C

Which of the following values is correct relating to this process? .....

(a) $q_p = 0$ (b) $\Delta H = 0$ (c) $\Delta H = +334$ J (d) $\Delta H = -334$ J

5 Which of the following statements represents the type of the chemical reaction which occurs on rubbing a wooden match against a rough surface ? .....

(a) Endothermic because of using energy on rubbing the wooden match.

(b) Endothermic because of releasing energy on burning the wooden match.

(c) Exothermic because of using energy on rubbing the wooden match.

(d) Exothermic because of releasing energy on burning the wooden match.

6 Benzene C_6H_6 combusts according to the following equation :

$$C_6H_{6(\ell)} + \frac{15}{2} O_{2(g)} \longrightarrow 6CO_{2(g)} + 3H_2O_{(\ell)}$$

Which of the following calculations estimates the standard heat of combustion of benzene ? .....

Compound	Standard heat of formation
$C_6H_{6(\ell)}$	+49 kJ/mol
$CO_{2(g)}$	–394 kJ/mol
$H_2O_{(\ell)}$	–286 kJ/mol

(a) $[(12 \times -394) + (6 \times -286)] - (2 \times 49)$

(b) $[(12 \times 394) + (6 \times 286)] - (2 \times -49)$

(c) $[(6 \times -394) + (3 \times -286)] - 49$

(d) $[(6 \times 394) + (3 \times 286)] - (-49)$

7 To raise the temperature of 15 g of the metal X from 25°C to 32°C, that requires an amount of heat equals 178.1 J,
What is the specific heat of the metal X ? .....

(a) 0.59 J/g.°C (b) 11.9 J/g.°C

(c) 1.7 J/g.°C (d) 25.4 J/g.°C

8 When 15.5 g of water at 10°C are provided with an amount of heat equal 5 kJ, water .....

(a) boils. (b) evaporates completely.

(c) freezes. (d) stays liquid.

9 What is the amount of released heat when 1.9×10^8 L of hydrogen gas combusts according to the equation : $H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(\ell)}$ $\Delta H = -286$ kJ/mol knowing that the molar volume of any gas (at STP) equals 22.4 L/mol ? .....

(a) 8.64×10^6 kJ (b) 2.98×10^{10} kJ

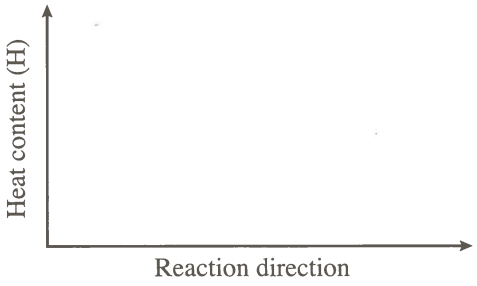
(c) 3.02×10^4 kJ (d) 2.43×10^9 kJ

10 Which of the following choices represents the compound which has higher thermal stability ? .....

Choices	(a)	(b)	(c)	(d)
Compound	$CdSO_4$	CdS	$Cd(OH)_2$	CdO
Standard heat of formation (kJ/mol)	–935	–162	–561	–258

11 Represent the following reaction by drawing its energy diagram on the figure shown below :

$$N_2H_{4(\ell)} + O_{2(g)} \longrightarrow N_{2(g)} + 2H_2O_{(v)} \quad \Delta H^\circ = -622 \text{ kJ/mol}$$



1 mark

12 The following diagram represents the changes in energy in two different processes :

W $\xrightarrow{\Delta H = -130 \text{ kJ/mol}}$ X $\xrightarrow{\Delta H = +80 \text{ kJ/mol}}$ Z

Calculate ΔH of the process Z $\longrightarrow$ W

.....

.....

.....

1 mark

13 Heat of solution ΔH_{sol} is estimated from the relation :

$$\Delta H_{sol} = \Delta H_1 + \Delta H_2 + \Delta H_3$$

If you know that the solution of calcium oxide in water is exothermic, so which of the previous values of ΔH is higher ? What does this value represent ?

.....

1 mark

14 In the bomb calorimeter, a gas and a liquid are used and they do not change when the heat of combustion of any matter is calculated..

What is the importance of the used gas ? What is the name of this liquid ?

.....

.....

.....

1 mark

Exam model

15 **In terms of the two following equations :**

① $NH_4NO_{3(s)} \xrightarrow{water} NH_4NO_{3(aq)}$ $\quad \Delta H^\circ_{sol} = +25.7$ kJ/mol

② $NaOH_{(s)} \xrightarrow{water} NaOH_{(aq)}$ $\quad \Delta H^\circ_{sol} = -51$ kJ/mol

(1) **Which of the previous** compounds its solution in water is endothermic ?

.....

(2) **Calculate the amount of heat (released or absorbed)** when 0.4 g of NaOH dissolves in water, knowing that its molar mass = 40 g/mol

.....

.....

.....

.....

.....

2 marks

16 Assisted by the values of the standard heat of combustion ΔH°_c of the compounds shown in the opposite table.. **Write the thermochemical equation** which represents the heat of formation of each of acetylene and carbon dioxide from their constituent elements.

Substance	Standard heat of combustion ΔH°_c (kJ/mol)
$C_{(s)}$	–393.5
$H_{2(g)}$	–285.85
$C_2H_{2(g)}$	–1300

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

2 marks

17 **Calculate ΔH of the reaction :** $4NH_{3(g)} + 7O_{2(g)} \longrightarrow 4NO_{2(g)} + 6H_2O_{(v)}$

By the indication of the following thermochemical equations :

① $N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)}$ $\quad \Delta H_1 = -180.5$ kJ

② $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$ $\quad \Delta H_2 = -91.8$ kJ

③ $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$ $\quad \Delta H_3 = -483.6$ kJ

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

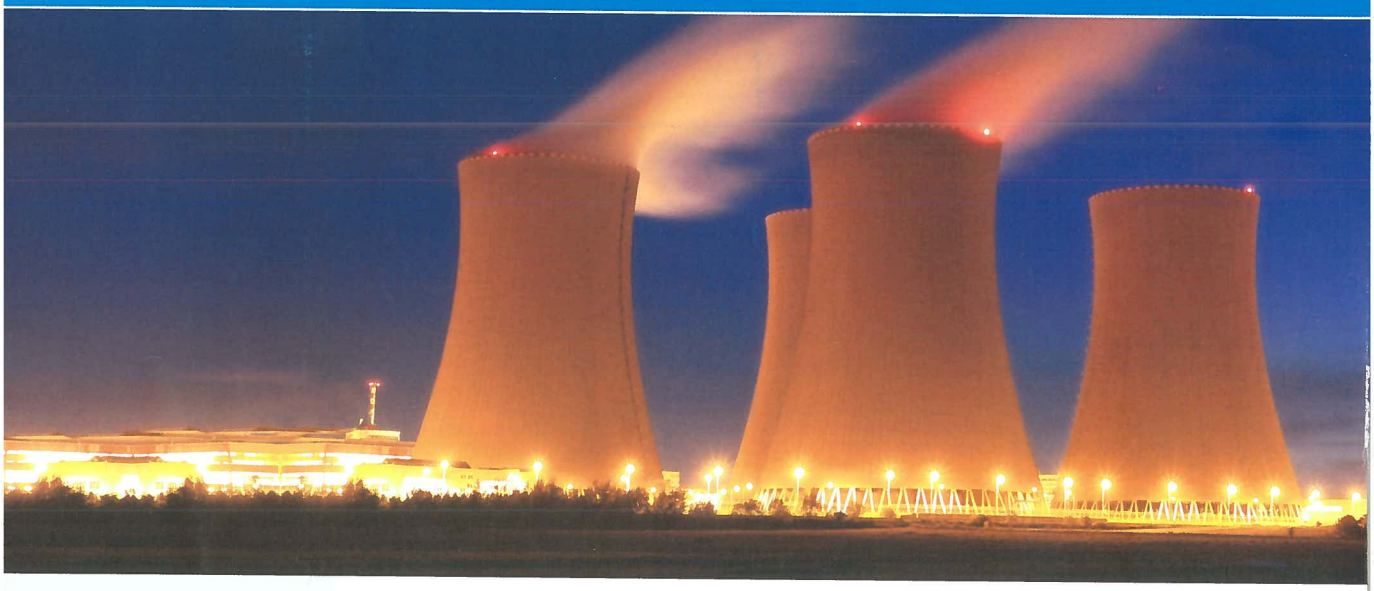
.....

.....

2 marks

UNIT 5

Nuclear Chemistry



Chapter One — Nucleus and Elementary Particles.

Lesson 1
From: Atom components.
Until: Before strong nuclear forces.

Lesson 2
From: Strong nuclear forces.
Until: The end of the chapter.

General exercises on the unit

Chapter Two — Radioactivity and Nuclear Reactions.

Lesson 1
From: Radioactivity and nuclear reactions.
Until: Before nuclear transformation.

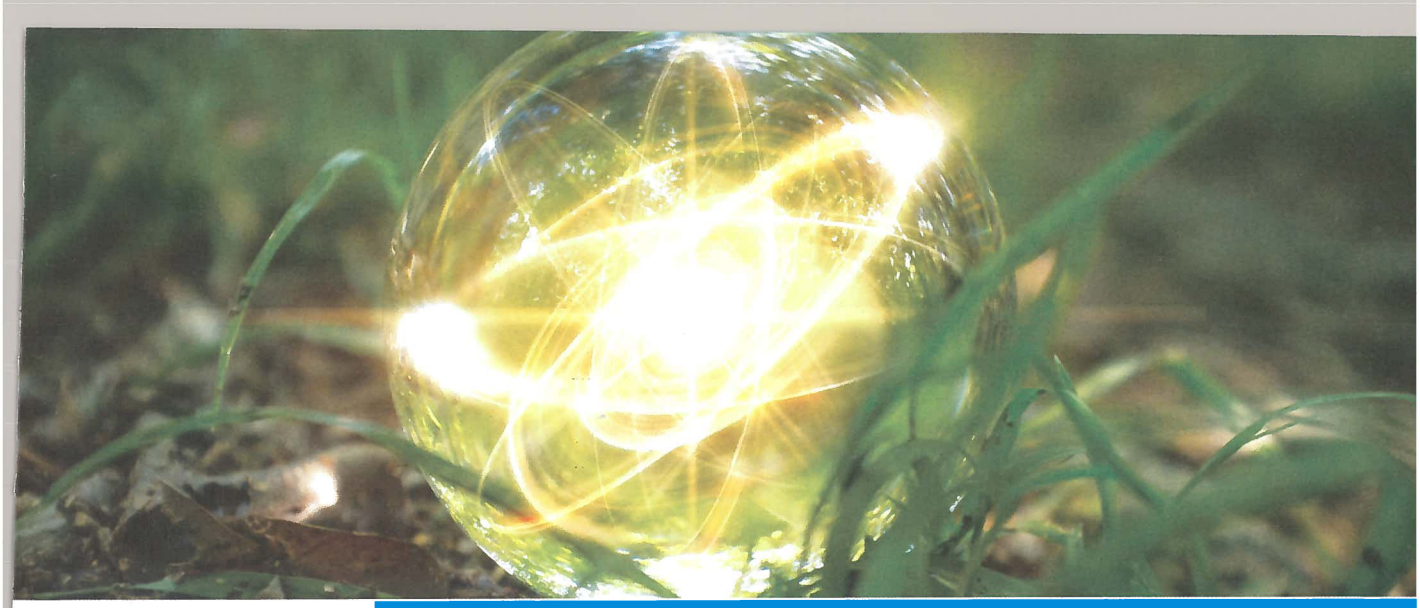
Lesson 2
From: Nuclear transformation.
Until: The end of the chapter.

Exam model about the unit

General objectives of unit five

By the end of this unit, the student will be able to :

- Identify the components of an atom.
- Describe the nuclear force found in the nucleus.
- Connect between the ratio of neutrons to protons and the nucleus stability.
- Define isotopes and mention examples.
- Understand the nuclear binding energy.
- Recognize the concept of quark and the types of quarks.
- Mention the historical timeline of the radioactivity phenomenon.
- Distinguish between the alpha particles, beta particles and gamma rays.
- Compare between the nuclear and chemical reactions.
- Compare between the nuclear fission and nuclear fusion.
- Know the harmful effects of rays.
- Recognize the appropriate usages of rays.



Unit 5

Chapter One

Lesson 1

From Atom components

Until Before strong nuclear forces

Atom components

- It is well known that matter is composed of atoms. These atoms show the physical and chemical properties of the matter.

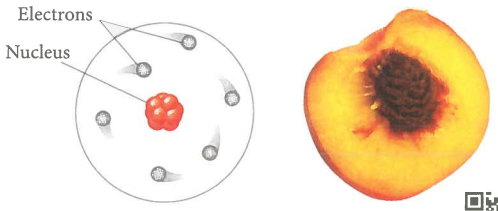
Discovery of electrons

- **By the end of the nineteenth century :**
  - Scientists had become sure that **electrons** are of the main components of the atom and they are particles with a very small mass, have a negative charge and rotate around the nucleus.
  - Since the atom is electrically neutral, So the atom has other particles carrying positive charges equal to the negative charges of the electrons.
    However, there was no known distribution for the positive and negative charges in the atom at that time.

Rutherford's (1911) and Bohr's (1913) atomic models

- According to the experiment of Rutherford's and Bohr's theories, the atomic structure became more acceptable as shown in the following table :

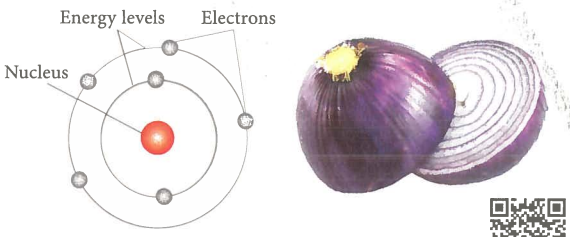
Rutherford's atomic model



Rutherford's atomic model

- In the center of the atom, there is a nucleus :
  - Tiny and positively charged.
  - Relatively heavy in which the mass of the atom is concentrated.
- Negative electrons rotate around the nucleus at a relatively far distance.
  - Most of the atomic volume is space. Where the volume of the nucleus is very small relative to the atom's volume.
  - The nucleus diameter = (10^{-6} : 10^{-5} nm), while the atom's diameter = 1×10^{-10} m (0.1 nm)

Bohr's atomic model



Bohr's atomic model

- The negatively charged electrons rotate around the nucleus in certain fixed orbits called energy levels.
- Each energy level is occupied by a certain number of electrons that can't be increased.

Discovery of protons (1919)

Rutherford proved that the nucleus of atom contains positively charged particles called protons.

Discovery of neutrons (1932)

Nevil Sidgwick discovered that the nucleus contains neutrally charged particles that are called neutrons, where the mass of the neutron is nearly similar to the mass of a proton.

Notes

* **The atom's mass is concentrated in the nucleus,** because the mass of electrons is too small (negligible) compared to the mass of protons and neutrons (mass of proton = 1800 times of the electron mass).
* **The atom is electrically neutral,** because the number of positively charged protons in the nucleus equals the number of negatively charged electrons rotating around the nucleus.

Description of the nucleus of the atom of any element

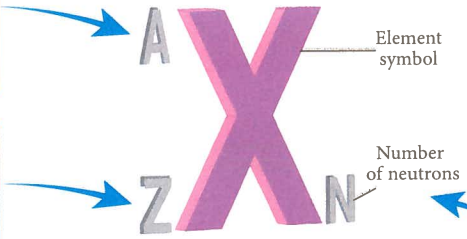
- **To describe the nucleus of the atom of any element, you should know the following three terms :**

Term	Symbol		Relation
Mass number	A	=	Number of protons + Number of neutrons
Atomic number	Z	=	Number of protons = Number of electrons (in the neutral atom)
Neutrons number	N	=	Mass number – Number of protons (N = A – Z)

- Any element can be represented **as follows :**

Mass number is the sum of the numbers of protons and neutrons inside the nucleus of the element atom.

Atomic number is the number of protons inside the nucleus of the element atom.



N = A – Z

- **Nucleons** are the protons and the neutrons inside the nucleus.

Example

Write the nucleus symbol of aluminum atom, **knowing that** its nucleus contains 13 protons and 14 neutrons.

Solution

Atomic number (Z) = No. of protons = 13

Mass number (A) = No. of protons + No. of neutrons

= 13 + 14 = 27

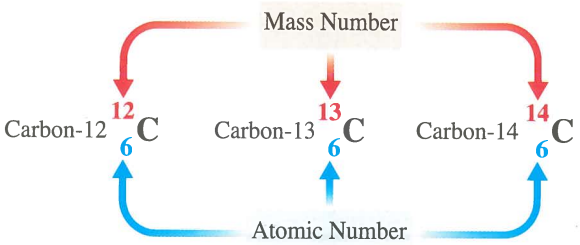
$^{27}_{13}Al_{14}$

Nucleus symbol of aluminum atom

Isotopes

- **Isotopes** are atoms of the same element that have the same atomic number (Z), but differ in mass number (A) due to the difference in the number of neutrons inside their nuclei.

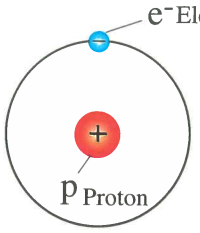
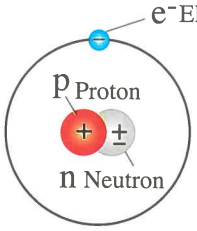
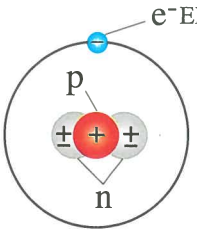
- The isotopes have the same chemical properties, **because** they have similar number of electrons and the same electronic configuration around the nucleus.
- **Most elements in the periodic table have more than one isotope.**



Isotopes of the same element have the same atomic number and differ in mass number

Application 1 Hydrogen isotopes :

Hydrogen is the simplest element in nature, it has three isotopes, **shown in the following table :**

Symbol of isotope	$^{1}_{1}H$	$^{2}_{1}H$	$^{3}_{1}H$
Name of the isotope	**Protium**	**Deuterium**	**Tritium**
Name of the nucleus	Proton	Deuteron	Triton
Structure			
Atomic number (Z) No. of protons (P)	1	1	1
Mass number (A)	1	2	3
No. of neutrons (N)	1 – 1 = 0	2 – 1 = 1	3 – 1 = 2

It is clear from the previous table that :

- The atomic number equals the mass number in protium nucleus, **because** it doesn't contain neutrons.
- **Number of neutrons equals :**
  - The number of protons in deuterium nucleus.
  - Double the number of protons in tritium nucleus.

Application 2 Oxygen isotopes :

Oxygen element has three isotopes, **shown in the following table :**

Isotope	$^{16}_{8}O$	$^{17}_{8}O$	$^{18}_{8}O$
No. of protons (P)	8	8	8
No. of nucleons (A)	16	17	18
No. of neutrons (N)	16 – 8 = 8	17 – 8 = 9	18 – 8 = 10

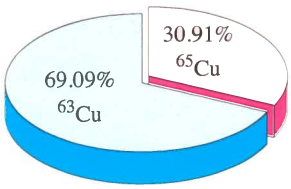
Atomic mass unit amu (u)

- Masses of atomic isotopes can't be measured in kg, **because** their masses are too small. So, they are measured in atomic mass unit **amu (u),**
  where **1 u** = 1.66×10^{-27} kg = 1.66×10^{-24} g
- Atomic masses of elements can be identified by knowing the relative atomic masses of their isotopes and the percentage of the presence of each of them.

Examples

1 **Calculate the atomic mass of copper,**
knowing that it is found in nature in the form of two isotopes ^{63}Cu (69.09%) and ^{65}Cu (30.91%).

[^{63}Cu = 62.9298 amu , ^{65}Cu = 64.9278 amu]



The percentage of copper isotopes in nature

Solution

The contribution of copper – 63 in the atomic mass = $62.9298 \times \frac{69.09}{100} = 43.4782$ u

The contribution of copper – 65 in the atomic mass = $64.9278 \times \frac{30.91}{100} = 20.0692$ u

∴ The atomic mass of copper Cu = 43.4782 + 20.0692

= 63.5474 u

2 A sample of lithium contains two isotopes, the first is lithium –6 and its atomic mass is 6.01572 u and the second is lithium –7 and its atomic mass is 7.016 u
Calculate the atomic mass of lithium element Li,
knowing that the percentage of lithium–6 found in the sample is 7.42%

Solution

The percentage of lithium –7 in the sample = 100 – 7.42 = 92.58%

The contribution of lithium –6 in the atomic mass = $6.01572 \times \frac{7.42}{100} = 0.4464$ u

The contribution of lithium –7 in the atomic mass = $7.016 \times \frac{92.58}{100} = 6.4954$ u

∴ The atomic mass of lithium element Li = 0.4464 + 6.4954 = 6.9418 u

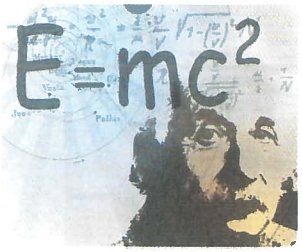
Relationship between mass and energy

- Calculation of the produced energy from the transformation of a mass of a substance (estimated in kilograms kg) to energy (estimated in Joules J).
  By applying **Einstein's equation** :

Energy (J) | Transformed mass (kg) | Square of light speed $(3\times10^8 \text{ m/s})^2$

$$E = m \times c^2$$

"Einstein's equation"



Einstein formulated a mathematical equation illustrates the relation between the transformed mass and energy

- Calculation of the produced energy from the transformation (conversion) of a mass of a substance (estimated in atomic mass unit u) to energy (estimated in million electron volt unit MeV).
  By using the following equation :

Energy (MeV) | Mass (u) | Constant value

$$E = m \times 931$$

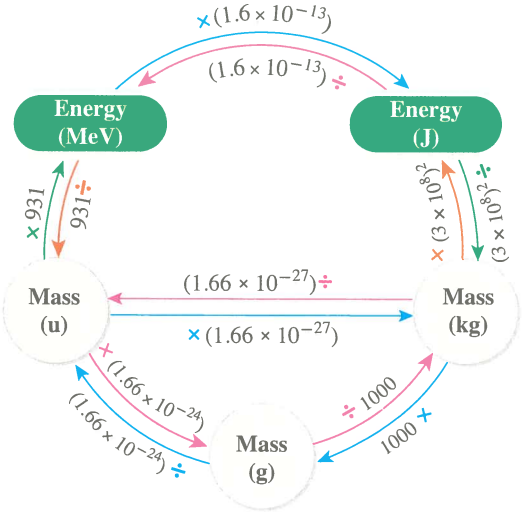
Do you know ?

$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

$\because 1 \text{ MeV} = 1 \times 10^6 \text{ eV}$

$\therefore 1 \text{ MeV} = 1.6 \times 10^{-13} \text{ J}$

The previous relations can be summed up in the following diagram :



Examples

1 Calculate the amount of energy produced from the transformation of 5 g of a substance, estimated in :

(1) Joule (J).

(2) Million electron volt (MeV).

Solution

to convert g ⟶ kg divide by 1000

(1) $m = \frac{5}{1000} = 0.005$ kg

$E\,(J) = m.c^2 = 0.005 \times (3 \times 10^8)^2 = 4.5 \times 10^{14}$ J

to convert g ⟶ u divide by 1.66×10^{-24}

(2) $m = \frac{5}{1.66 \times 10^{-24}} = 3.012 \times 10^{24}$ u

$E\,(MeV) = m \times 931 = 3.012 \times 10^{24} \times 931 = 2.8 \times 10^{27}$ MeV

* To confirm the results divide the value of energy in (J) unit by 1.6×10^{-13}

$E = \frac{4.5 \times 10^{14}}{1.6 \times 10^{-13}} = 2.8 \times 10^{27}$ MeV

2 **Calculate the amount of energy (in Joule)** produced from the transformation of 25% of 1.4 g of a radioactive substance to energy.

Solution

$m = 1.4 \times \frac{25}{100} = 0.35$ g

$E = m.c^2 = \frac{0.35}{1000} \times (3 \times 10^8)^2 = 3.15 \times 10^{13}$ J

3 **Calculate the mass (in kg)** required to produce an amount of energy equals 190 MeV

Solution

$m\,(u) = \frac{E}{931} = \frac{190}{931} = 0.204$ u

to convert u ⟶ kg multiply by 1.66×10^{-27}

$m\,(kg) = 0.204 \times 1.66 \times 10^{-27} = 3.38 \times 10^{-28}$ kg

Another solution

$E\,(J) = 190 \times 1.6 \times 10^{-13} = 3.04 \times 10^{-11}$ J

$m\,(kg) = \frac{E}{c^2} = \frac{3.04 \times 10^{-11}}{(3 \times 10^8)^2} = 3.38 \times 10^{-28}$ kg

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Complete the following table :

Element symbol		Atomic number (Z)	Mass number (A)	No. of protons (P)	No. of neutrons (N)
(1)	$^{4}_{2}He$	.....	.....	.....	.....
(2)	$^{12}_{6}C$	.....	.....	.....	.....
(3)	$^{40}_{20}Ca$	.....	.....	.....	.....

2 Choose the correct answer :

(1) The mass of atom is concentrated in the .....

a. nucleus. b. protons. c. neutrons. d. electrons.

(2) The chemical symbol of the nucleus of aluminum atom which contains 13 protons, 14 neutrons is .....

a. $^{14}_{27}Al$ b. $^{27}_{14}Al$ c. $^{13}_{27}Al$ d. $^{27}_{13}Al$

(3) The term nucleons indicates .....

a. protons and electrons. b. alpha particles and beta particles.

c. electrons and neutrons. d. neutrons and protons.

(4) The nucleus of each of the following contains neutrons, except .....

a. deuterium b. protium c. tritium d. triton

(5) Each of the following is one of the energy units, except .....

a. MeV b. J c. amu d. eV

(6) The energy produced from the conversion of mass 1 u into energy = ... MeV

a. 931×10^{6} b. 931 c. 1.489×10^{-10} d. 1.545×10^{-24}

4 Explain why :

(1) The atom is electrically neutral.

(2) The isotopes of the same element are similar in atomic number but different in mass number.

(3) The isotopes of an element have the same chemical properties.

(4) The atomic number (Z) of protium = the mass number (A).

(5) Protium, deuterium and tritium are different isotopes of the same element.

Steady

Open book questions

Answered

Multiple choice questions

1 Which of the following choices represents both the numbers of the protons and the neutrons in the nucleus of cobalt element $^{60}_{27}Co$ respectively ? .....

(a) 60 , 33 (b) 27 , 33 (c) 27 , 60 (d) 27 , 87

2 Which of the following pairs of elements atoms their nuclei contain the same number of neutrons ? .....

(a) $^{12}_{5}B$, $^{12}_{6}C$ (b) $^{1}_{1}H$, $^{2}_{1}H$

(c) $^{12}_{6}C$, $^{13}_{7}N$ (d) $^{14}_{6}C$, $^{14}_{7}N$

3 On comparing the charge of the proton with the charge of the electron, the charge of the proton is .....

(a) higher than that of the electron and with the same sign.
(b) higher than that of the electron and with opposite sign.
(c) equal to that of the electron and with the same sign.
(d) equal to that of the electron but with opposite sign.

Questions marked by this mark are for the superiors and their ideas are explained in the answers

4 The opposite table illustrates the masses of two kinds of the atom particles .. What are they ? .....

Atom particles	Mass
(X)	1.67×10^{-24} g
(Y)	9.11×10^{-28} g

(a) X is a proton, Y is an electron.
(b) X is a proton, Y is a neutron.
(c) X is a neutron, Y is a proton.
(d) X is an electron, Y is a proton.

5 What is the number of nucleons found in the nucleus of the isotope of $^{84}_{36}Kr$? .....

(a) 36 (b) 48 (c) 84 (d) 120

6 The isotope of the element $^{112}_{50}X$ is .....

(a) $^{112}_{51}X$ (b) $^{113}_{51}X$ (c) $^{112}_{49}X$ (d) $^{113}_{50}X$

7 The isotope chlorine –37 differs from chlorine –35 in containing .....

(a) one more neutron and one more electron.
(b) one more proton and one more electron.
(c) two more neutrons.
(d) two more protons.

8 **Which of the following statements states the relation between the number of neutrons and that of protons in tritium nucleus ?** .....

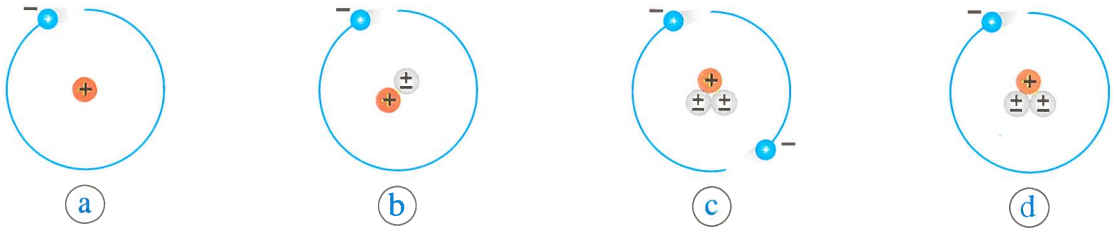
(a) Number of neutrons equals that of protons.

(b) Number of neutrons is half that of protons.

(c) Number of neutrons is double that of protons.

(d) Number of neutrons is four times as that of protons.

9 **Which of the following figures represents the tritium isotope ?** .....



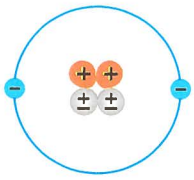
(a) (b) (c) (d)

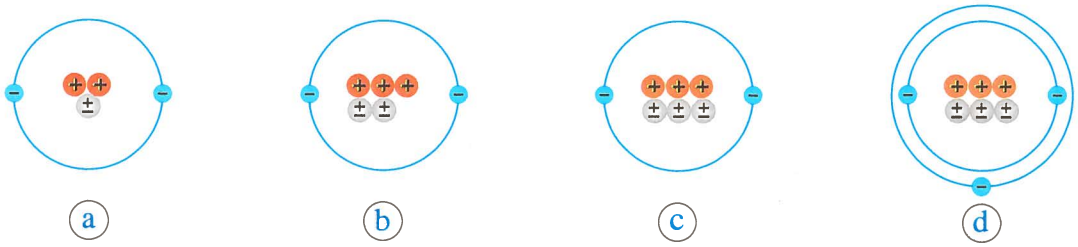
10 **Which of the following choices represents two isotopes of one element ?** .....

(1) (2) (3) (4)

(a) (1) , (2). (b) (1) , (3). (c) (2) , (3). (d) (2) , (4).

11 **The opposite figure illustrates the structure of an atom.. Which of the following figures illustrates an isotope of this atom ?** .....





(a) (b) (c) (d)

12 **The atomic number of iron is 26 and it's found in nature in the form of four isotopes (^{54}Fe , ^{56}Fe , ^{57}Fe , ^{58}Fe).. Which of the following statements explains the reason for all these isotopes having the same chemical properties ? They have the same** .....

(a) mass number. (b) number of nucleons.

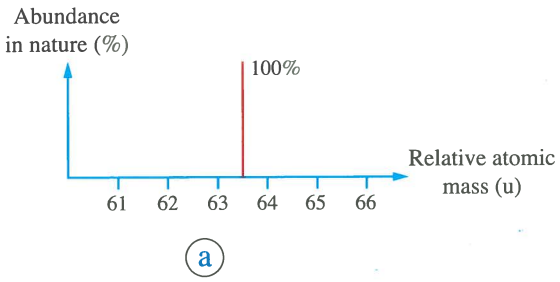
(c) number of neutrons. (d) number of electrons in the last energy level.

13 The opposite table shows the masses of two isotopes of chlorine and their abundance in nature.. Which of the following relations represents the method of calculation of the atomic mass of chlorine ? .....

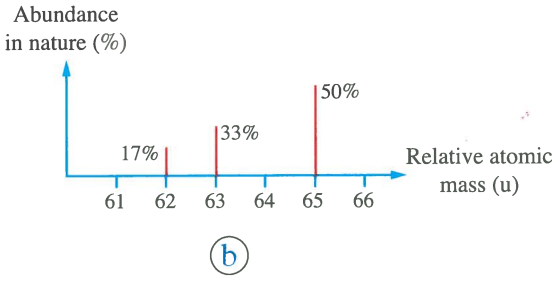
Isotope	Relative atomic mass	Abundance in nature
^{35}Cl	34.97 u	75.76%
^{37}Cl	36.97 u	24.24%

(a) (34.97) (75.76) + (36.97) (24.24).
(b) (34.97) (0.2424) + (36.97) (0.7576).
(c) (34.97) (0.7576) + (36.97) (0.2424).
(d) (34.97) (24.24) + (36.97) (75.76).

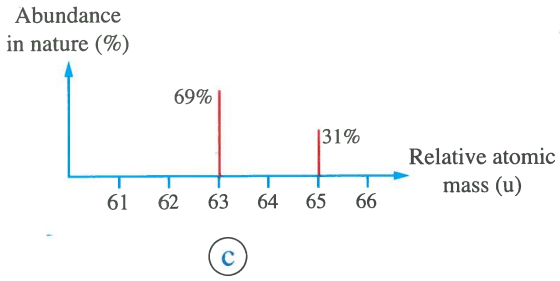
14 The relative atomic mass of copper element is 63.6 u.. Which of the following graphical figures represents the percentage of presence of copper isotopes in nature and the relative atomic mass of each of them ? .....



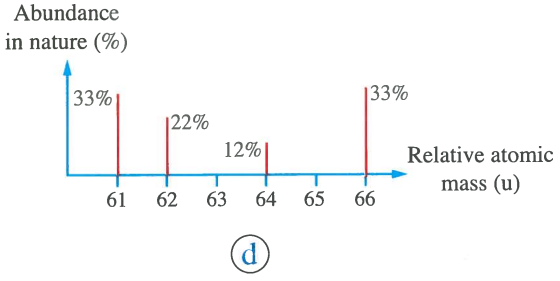
(a)



(b)



(c)



(d)

15 The opposite table represents some data about two new elements added to the modern periodic table .. Which of the following statements does not represent correctly these two elements ? .....

Element	Uuq	Uuh
Number of protons	114	116
Number of nucleons	289	292

(a) Nucleus of Uuh atom contains one more neutron than the number of neutrons in nucleus of Uuq atom.
(b) Uuq^{2-} ion contains the same number of electrons present in Uuh atom.
(c) Uuh^{+} ion contains the same number of electrons present in Uuq atom.
(d) Uuq^{2-} ion contains the same number of protons present in Uuq^{+} ion.

Essay questions

16 **What are the results** of the similarity of the isotopes of the same element in the number of electrons which revolve around the nucleus of the atom of each isotope ?

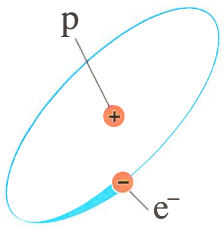
17 **Write the chemical symbol of nuclei of the following isotopes :**

(1) Element X (A = 65 , Z = 29).

(2) Element Y (N = 25 , Z = 20).

(3) Element Z (A = 84 , N = 48).

18 **The opposite figure refers to a hydrogen isotope :**



(1) What is the name of this isotope ?

What is the name of its nucleus ?

(2) What is the number of nucleons in this isotope ?

and what are their types ?

19 **An atom of one of sodium isotopes contains :**

(11 protons , 11 electrons , 13 neutrons)

(1) Which of the previous numbers doesn't change in neutral sodium isotopes ?

(2) What is the number of nucleons in this isotope ?

(3) Write your observations about the chemical properties of the different sodium isotopes.

20 **Astatine (At) element has many isotopes, the most important of them is astatine–210 which has 85 electrons revolve around its nucleus :**

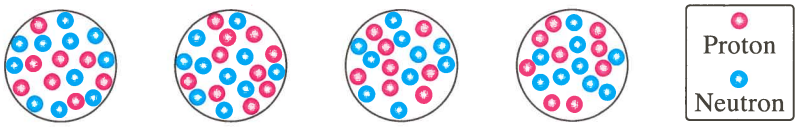
(1) What is meant by that astatine element has many isotopes ?

(2) What is the atomic number of astatine ?

(3) How many neutrons found in the nucleus of this isotope ?

(4) Write the nucleus symbol of this isotope.

21 **The following four figures represent four nuclei of four different atoms :**



(1) (2) (3) (4)

(1) What is the mass number of nucleus (2) ?

(2) Why are the nuclei (1) and (3) isotopes for the same element ?

22 **Calculate the atomic mass of galium (Ga),**

knowing that it is found in nature in the form of two isotopes, **which are :**

* ^{69}Ga (60.11%) and its relative atomic mass = 68.93 u

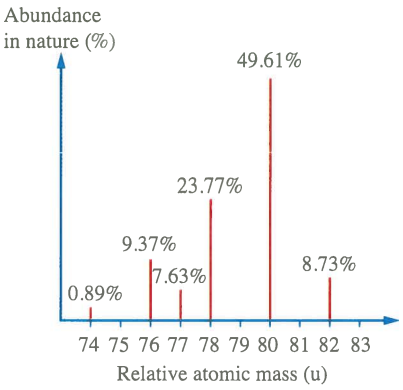
* ^{71}Ga (39.89%) and its relative atomic mass = 70.92 u

23 **Assisted by the following table** which shows the masses and the percentages of three isotopes of magnesium found in nature ..

Calculate the atomic mass of magnesium.

Isotope	^{24}Mg	^{25}Mg	^{26}Mg
Relative atomic mass	23.985 u	24.986 u	25.983 u
Abundance in nature	78.7%	10.13%	11.17%

24 **Study the opposite graph which shows** the percentages of presence of isotopes of an element X in nature, and the relative atomic mass of each isotope, then **calculate the atomic mass of the element X.**



25 **Calculate the amount of energy** produced from the transformation of 0.2 g of a substance into energy measured in :

(1) Joule (J).

(2) Million electron volt (MeV).

26 **Calculate the amount of energy** in MeV liberated from 0.00234 u of platinum– 215 when converted to energy.

27 **Calculate the amount of energy** produced from the transformation of 50% of 10 g of a radioactive substance, measured in :

(1) Joule (J).

(2) Million electron volt (MeV).

28 Using Einstein's equation, **calculate the mass** (in kg) required to be converted to energy which equals 190 MeV.

29 **Calculate the mass** transformed into 6.8419 MeV in :

(1) Atomic mass unit (u). **(2)** Gram (g).

New types of questions ? Answered

Choosing two out of five choices questions :

1 These are five different isotopes :

$^{35}_{17}X$	$^{37}_{17}X$	$^{38}_{18}X$	$^{81}_{35}X$	$^{81}_{37}X$
(1)	(2)	(3)	(4)	(5)

Which of the following choices are two isotopes for the same element ? .....

(a) Isotope (1). (b) Isotope (2). (c) Isotope (3).

(d) Isotope (4). (e) Isotope (5).

2 What are the two correct relations among the following ? .....

(a) $2\ MeV = 2 \times 10^{5}\ eV$

(b) $2\ eV = 2 \times 10^{6}\ J$

(c) $2\ MeV = 3.2 \times 10^{-26}\ J$

(d) $2\ eV = 3.2 \times 10^{-19}\ J$

(e) $2\ MeV = 3.2 \times 10^{-13}\ J$

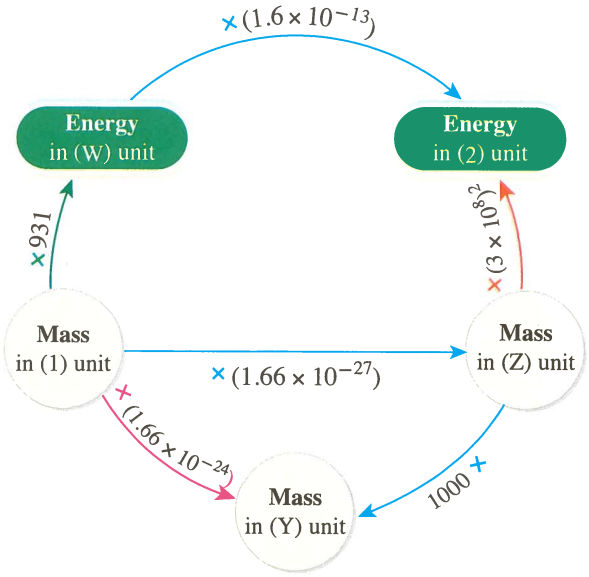
The sketch questions :

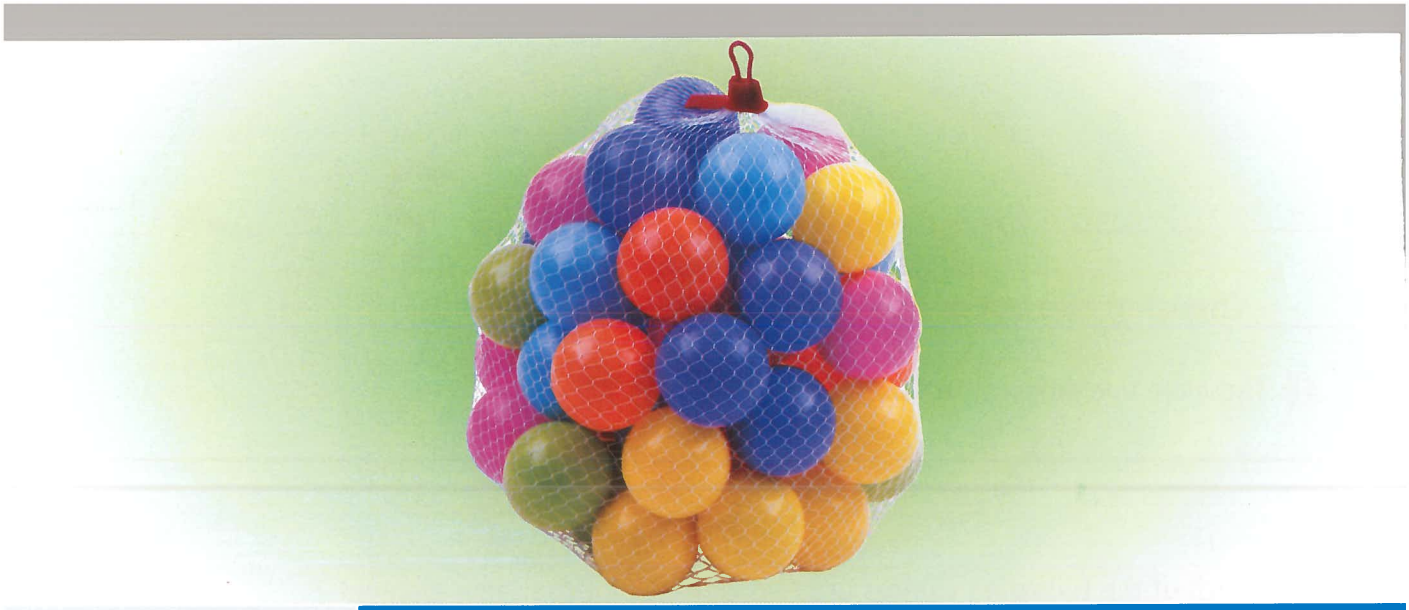
3 The opposite sketch shows the relations between mass and energy ..

Choose from the following list what is suitable for each of (1) and (2) :

Joule	Atomic mass unit	Calorie
MeV	Kilogram	Gram

- (1) refers to .....
- (2) refers to .....





Unit 5

Chapter One

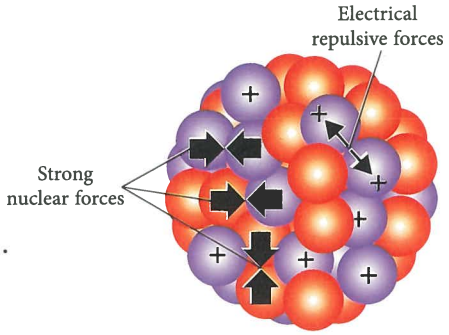
Lesson 2

From Strong nuclear forces

Until The end of the chapter

Strong nuclear forces

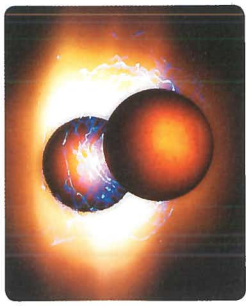
- The nucleus keeps its stability in spite of the huge electric repulsive forces (named coulomb electric forces) between the positive protons compared to the small attractive forces between the nucleons, **due to the presence of** other forces working on combining these nucleons called the strong nuclear forces. These forces are named strong nuclear forces, **because** they have a great effect on the nucleons inside the small nucleus.



Nuclear forces

Properties of the strong nuclear forces

1. They have a great power.
2. They do not depend on the type of the charge of nucleons, but they may exist between :
   - proton - proton.
   - neutron - neutron.
   - proton - neutron.
3. They are short-range forces (work only when spaces between nucleons are very small).



Imaginary shape in which the nucleons are represented by the balls and the strong nuclear forces are represented by the blue color

Note

It is impossible for the isotope $^{2}_{2}He$ to exist naturally,
as the electrical repulsion forces between the protons will not be offset by attraction forces between protons and neutrons, as the nucleus does not contain neutrons

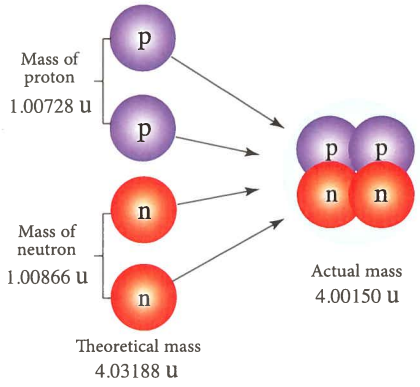
Nuclear binding energy

- Many accurate measurements **proved that :**
  The mass of the binded nucleons (actual mass of nucleus) is less than the mass of the free nucleons (theoretical mass of nucleus), **where :**

Mass defect = Theoretical mass – Actual mass

Application **Calculation of the mass defect in the nucleus of helium atom ^4_2He**

Imaginary figure for the nucleus of helium atom ^4_2He



Actual mass (4.00150 u) of ^4_2He nucleus is less than theoretical mass (4.03188 u)

- Loss in mass (Mass defect) = Theoretical mass – Actual mass
  = 4.03188 – 4.00150 = 0.03038 u
- It is found that the actual mass of nucleus of any atom is less than the theoretical mass, **because** a part of the mass of the nucleus components **is converted into** energy to bind the components together in the nucleus.
- This resulting energy which is equivalent to the amount of decrease in mass of the components of the nucleus is known as **the nuclear binding energy**.
- The nuclear binding energy (BE) can be calculated using Einstein's law, **as follows :**

Nuclear binding energy (BE) = Mass defect × 931
"MeV" "u"

- The value in which each nucleon contributes to the binding energy of the nucleus is called binding energy per nucleon.
  It can be calculated from the following relation :

$$\text{Binding energy per nucleon} = \frac{\text{Binding energy (BE)}}{\text{Mass number (No. of nucleons) (A)}}$$

- Nuclear binding energy per nucleon $\left(\frac{BE}{A}\right)$ is considered as a suitable measure for the nuclear stability, **because** the nuclear stability increases by increasing the value of the binding energy per nucleon $\left(\frac{BE}{A}\right)$.

Examples

1 **Calculate the nuclear binding energy per nucleon** in the nucleus of helium atom $^{4}_{2}He$, **knowing that** its actual mass = 4.00150 u, mass of proton = 1.00728 u and mass of neutron = 1.00866 u

Idea of solution

1 Calculate the theoretical mass of the nucleus constituents : Theoretical mass = [No. of protons × Mass of proton] + [No. of neutrons × Mass of neutron]	Theoretical mass = (2 × 1.00728) + (2 × 1.00866) = 4.03188 u
2 Calculate the loss in mass of the nucleus constituents : Mass defect = Theoretical mass – Actual mass	Mass defect = 4.03188 – 4.00150 = 0.03038 u
3 Calculate the nuclear binding energy (BE) : BE = Mass defect × 931	BE = 0.03038 × 931 = 28.28378 MeV
4 Calculate the nuclear binding energy per nucleon : Nuclear binding energy per nucleon = $\frac{\text{Nuclear binding energy}}{\text{No. of nucleons}} = \frac{BE}{A}$	$\frac{BE}{A} = \frac{28.28378}{4} =$ 7.070945 MeV

2 **Calculate the actual mass** of the nucleus of silicon atom $^{28}_{14}Si$, **knowing that :**

- Neutron mass = 1.00866 u
- Proton mass = 1.00728 u
- Binding energy per nucleon = 8.21275 MeV

Solution

Binding energy = Binding energy per nucleon × No. of nucleons

= 8.21275 × 28 = 229.957 MeV

Mass defect = $\frac{\text{Binding energy}}{931} = \frac{229.957}{931}$ = 0.247 u

Number of neutrons = Mass number – Atomic number = 28 – 14 = 14 neutrons

Theoretical mass = (Number of protons × Proton mass) + (Number of neutrons × Neutron mass)

= (14 × 1.00728) + (14 × 1.00866) = 28.22316 u

Actual mass = Theoretical mass – Mass defect

= 28.22316 – 0.247 = 27.97616 u

3 **Calculate the nuclear binding energy in Joule of an atom's nucleus,**

knowing that : The value of : A = 6 , Z = 3 , Actual mass = 6.015 u ,

Mass of proton = 1.00728 u , Mass of neutron = 1.00866 u

Solution

(No. of neutrons) N = (Mass number) A – (Atomic number) Z

= 6 – 3

= 3 neutrons

Theoretical mass = (No. of protons × Proton mass) + (No. of neutrons × Neutron mass)

= (3 × 1.00728) + (3 × 1.00866)

= 3.02184 + 3.02598 = 6.04782 u

Mass defect = Theoretical mass – Actual mass

= 6.04782 – 6.015 = 0.03282 u

Binding energy (BE) = Mass defect × 931

= 0.03282 × 931

= 30.55542 MeV

Binding energy (J) = Binding energy (MeV) × 1.6×10^{-13}

= $30.55542 \times 1.6 \times 10^{-13}$

= 4.9×10^{-12} J

Another solution

* The mass defect is converted from u to kg by multiplying × 1.66×10^{-27}

* Mass defect (kg)

= $0.03282 \times 1.66 \times 10^{-27}$

= 5.44812×10^{-29} kg

Nuclear binding energy (BE)

= Mass defect (kg) × c^2

= $5.44812 \times 10^{-29} \times (3 \times 10^8)^2$

= 4.9×10^{-12} J

4 **Which isotope** of oxygen isotopes ($^{16}_{8}O$ / $^{17}_{8}O$) is more stable ? **Giving reason.**

Where the actual mass of $^{16}_{8}O$ = 15.994915 u, the actual mass of $^{17}_{8}O$ = 16.999132 u,

neutron mass = 1.00866 u and proton mass = 1.00728 u

Solution

$^{16}_{8}O$		$^{17}_{8}O$
	Theoretical mass	
$(8 \times 1.00728) + (8 \times 1.00866)$ $= 16.12752$ u		$(8 \times 1.00728) + (9 \times 1.00866)$ $= 17.13618$ u
	Mass defect	
$16.12752 - 15.994915 = 0.132605$ u		$17.13618 - 16.999132 = 0.137048$ u
	Nuclear binding energy (BE)	
$BE = 0.132605 \times 931 = 123.455255$ MeV		$BE = 0.137048 \times 931 = 127.591688$ MeV
	Binding energy per nucleon	
$\frac{BE}{A} = \frac{123.455255}{16} =$ 7.7 MeV		$\frac{BE}{A} = \frac{127.591688}{17} =$ 7.5 MeV

So, the oxygen isotope $^{16}_{8}O$ is more stable than $^{17}_{8}O$, because the binding energy per nucleon $\left(\frac{BE}{A}\right)$ in $^{16}_{8}O$ is greater than that of $^{17}_{8}O$

5 Calculate the atomic number of an element, knowing that :

- Its binding energy = 27.36 MeV
- Its binding energy per nucleon = 6.84 MeV
- Mass of neutrons = 2.01732 u
- Mass of neutron = 1.00866 u

Solution

$$\text{Number of nucleons} = \frac{\text{Binding energy}}{\text{Binding energy per nucleon}}$$

$$= \frac{27.36}{6.84} = 4 \text{ nucleons}$$

$$\text{No. of neutrons} = \frac{\text{Mass of neutrons}}{\text{Mass of neutron}} = \frac{2.01732}{1.00866}$$

$$= 2 \text{ neutrons}$$

∴ The atomic number = Number of nucleons – Number of neutrons

$$= 4 - 2 = 2$$

Nuclear stability

- The nuclear stability is a concept that helps to identify the probability of the nucleus of element's atom to decay with time, hence the elements can be classified according to their nuclear stability into :

Stable elements

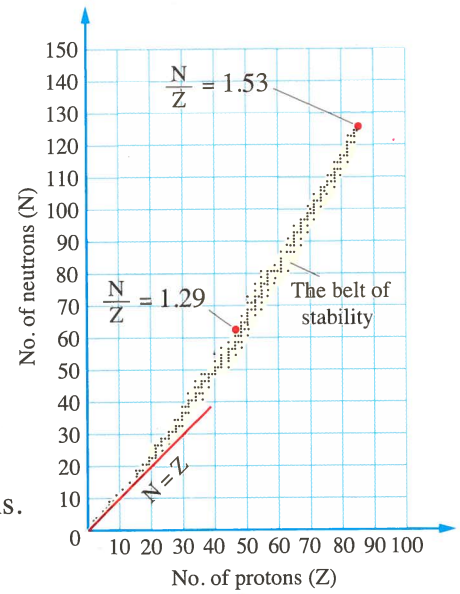
Stable element is the element in which its atom's nucleus remains stable through time without any radioactivity

Unstable elements

Unstable element is the element in which its atom's nucleus decays through time as a result of radioactivity

- **The ratio between the number of neutrons and protons $\left(\frac{N}{Z}\right)$ determines the extent of the nuclear stability.**

☆ **The opposite graph shows the relation between the number of neutrons and the number of protons of some of the elements of the periodic table, and it clarifies that :**



Stability diagram "stable nuclei form what is known as the belt of stability"

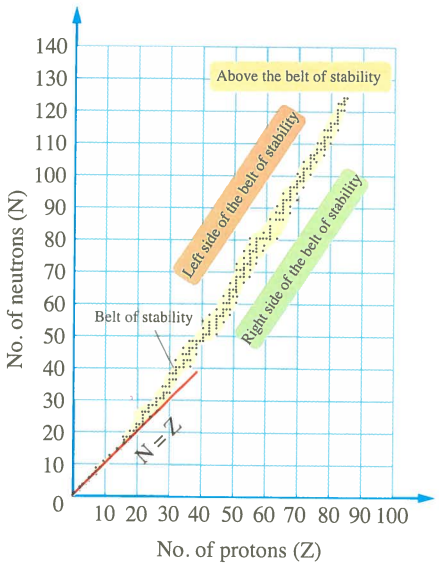
1. Atoms' nuclei of the stable elements :
   - Forms a region which deviates slightly to the left from the theoretical line which represents N = Z, this region is formed by the nuclei of the stable elements and is named **"belt of stability"**.
   - The number of neutrons equals the number of protons.

   i.e. The ratio $\left(\frac{N}{Z}\right)$ of their nucleons equals 1

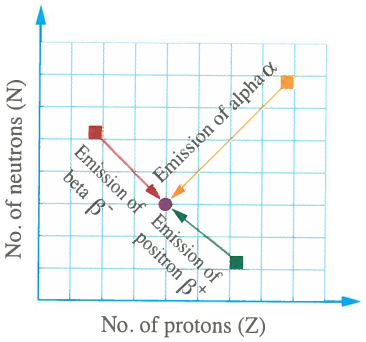
   e.g. : Light elements (whose nucleons number is less than 38), such as carbon $^{12}_{6}C$ and oxygen $^{16}_{8}O$
   - The ratio $\left(\frac{N}{Z}\right)$ increases gradually by increasing the atomic number till the ratio $\left(\frac{N}{Z}\right)$ reaches its maximum, which is 1.53 in the nucleus of lead isotope $^{208}_{82}Pb$

② Atoms' nuclei of the unstable elements :

Are located at the right side, the left side or above the belt of stability, and the following diagrams show the location of the unstable elements regarding to the belt of stability, the reason of their unstability and how they can reach the stability state by emitting certain particles through radioactivity :



Location of atoms' nuclei of unstable elements in relation to the belt of stability



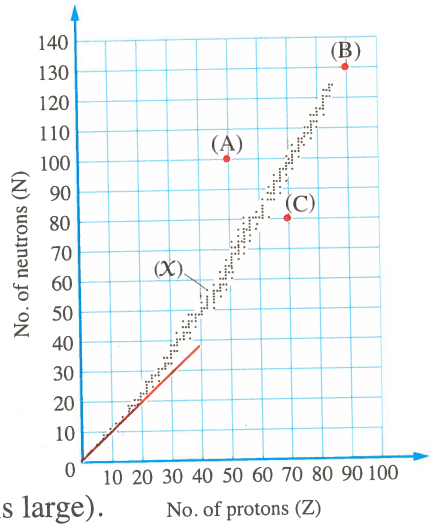
How atoms' nuclei of unstable elements reach the stability state

★ **The following table illustrates the reason of instability of atoms' nuclei and how they can reach stability state :**

Location	The reason of the instability of atoms' nuclei	How the unstable nuclei reach the stability state
At the left side of the belt of stability, as $^{14}_{6}C$	No. of neutrons is larger than the stability level ($\frac{N}{Z}$ ratio is large)	By emitting beta particles β^- (negative nucleus electron) from the atom's nucleus of the unstable element, to transform one of the extra neutrons to a proton and $\frac{N}{Z}$ ratio approaches the belt of stability $n \xrightarrow[\beta^-\text{-particle}]{\text{Emission of}} p$
At the right side of the belt of stability, as $^{35}_{19}K$	No. of protons is larger than the stability level ($\frac{N}{Z}$ ratio is small)	By emitting positron β^+ (positive nucleus electron) from the atom's nucleus of the unstable element, to transform one of the extra protons into a neutron and $\frac{N}{Z}$ ratio approaches the belt of stability $p \xrightarrow[\text{positron } \beta^+]{\text{Emission of}} n$
Above the belt of stability, as $^{238}_{92}U$	No. of nucleons is larger than the stability level	By emitting alpha particles α ($^{4}_{2}He$) from the atom's nucleus of an unstable element, to lose (2 protons, 2 neutrons) to approach the belt of stability

Examples

1 Study the opposite graph and answer the following :



(1) What does (X) represent ?

(2) A, B and C are three unstable nuclei of elements' atoms, which one of them acquires its stability by emission of :

a. β^--particle. **b.** Positron β^+

Then explain why ?

Solution

(1) Belt of stability.

(2) a. Nucleus of element (A) / because the number of neutrons is larger than the stability level ($\frac{N}{Z}$ ratio is large).

b. Nucleus of element (C) / because the number of protons is larger than the stability level ($\frac{N}{Z}$ ratio is small).

2 Elements X and Y have the same number of nucleons, the ratio $\frac{N}{Z}$ of the element X equals 1, and that of the element Y equals 1.5,
Conclude the chemical symbol of the stable element Y, knowing that the nucleus of the element X contains 5 protons.

Solution

* **For element X :**

$\because \frac{N}{Z} = 1$, $Z = 5$ $\therefore N = 5$

$\therefore$ Number of nucleons of the nucleus of X element or Y element = 5 + 5 = 10 nucleons

* **For element Y :**

$\because N : Z = 1.5 : 1 = 6 : 4$

$\therefore N = 6$ $Z = 4$

$\therefore$ The chemical symbol of the element Y is $^{10}_{4}Y$

Another solution (For element Y)

$\because \frac{N}{Z} = 1.5$ $\therefore N = 1.5\ Z$

$\because N + Z = 10$ $\therefore 1.5\ Z + Z = 10$

$2.5\ Z = 10$ $\therefore Z = 4$

$\therefore N = 1.5 \times 4 = 6$

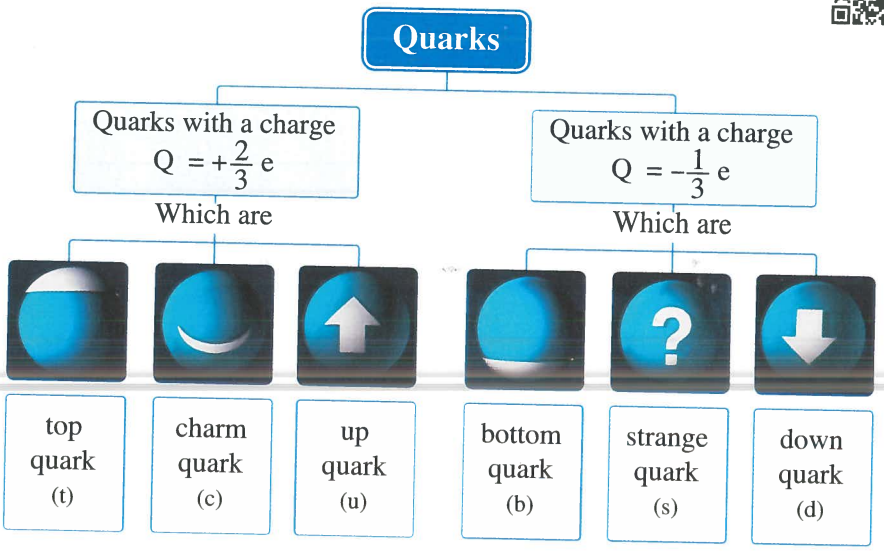
$\therefore$ The chemical symbol of the element Y is $^{10}_{4}Y$

Concept of quark

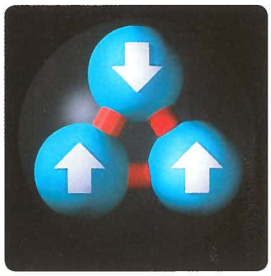
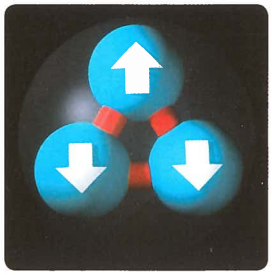
- In 1963, the scientist Murry Gell-Mann proved that the protons are formed from primary particles called quarks, **where :**
- Each of them is characterized by a number which is called Q that expresses its charge.
- They take values relative to the electron's charge and their values are $+\frac{2}{3}$ e **or** $-\frac{1}{3}$ e
- Their known number is six types.

Murry Gell-Mann

* **There are six types of quarks as shown in the following scheme :**



Composition of the proton and the neutron

Proton	Neutron
Composition	
It is composed of combination of 1 down quark (d) and 2 up quarks (u)	It is composed of combination of 1 up quark (u) and 2 down quarks (d)
	
The electric charge	
Electric charge of proton Q_p is positive	Electric charge of neutron Q_n is neutral
Explanation	
Because the charge of proton equals the sum of charges of quarks forming it	Because the charge of neutron equals the sum of charges of quarks forming it
$Q_p = d + u + u$ $= -\frac{1}{3} + \frac{2}{3} + \frac{2}{3} = +1\ e$	$Q_n = u + d + d$ $= \frac{2}{3} + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) = 0$

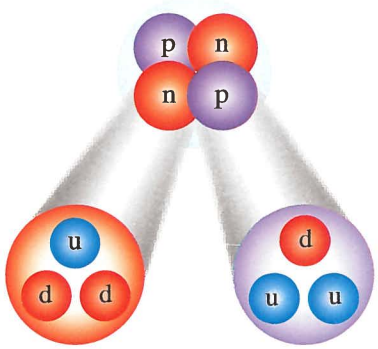
Examples

1 **Show the composition of the quarks in the nucleus of helium atom ^4_2He**

Solution

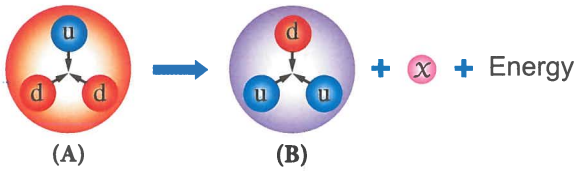
The nucleus of helium atom consists of :

- 2 protons (each one is composed of combination of 1 (d) quark with 2 (u) quarks).
- 2 neutrons (each one is composed of combination of 1 (u) quark with 2 (d) quarks).



Quarks composition in the helium nucleus

2 Study the opposite figure, then answer the questions :



(1) What does each of (A) & (B) represent ?
Then calculate the charge of each one.

(2) What is the particle (X) ? And what is its charge ?

Solution

(1) (A) is a neutron, $Q_n = \frac{2}{3} + (-\frac{1}{3}) + (-\frac{1}{3}) = 0$

(B) is a proton, $Q_p = -\frac{1}{3} + \frac{2}{3} + \frac{2}{3} = +1\,e$

(2) (X) is a beta β^--particle, and its charge is negative.

3 An element with atomic number 9, its nucleus contains 29 down quarks, Calculate :

(1) The mass number of the element.

(2) Number of up quarks in this element nucleus.

Solution

(1) Atomic number = Number of protons = 9

$\because$ Each proton is composed of the combination of 1 down quark (d) with 2 up quarks (u)

$\therefore$ Number of down quarks in the protons = 9 down quarks

$\therefore$ Number of down quarks in the neutrons = 29 – 9 = 20 down quarks

$\because$ Each neutron is composed of the combination of 1 up quark (u) with 2 down quarks (d)

$\therefore$ Number of neutrons = $\frac{20}{2}$ = 10 neutrons

$\therefore$ Mass number = No. of protons + No. of neutrons

= 9 + 10 = 19

(2) Number of up quarks in the element nucleus

= No. of up quarks in the protons + No. of up quarks in the neutrons

= (2 × 9) + (1 × 10) = 28 up quarks

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Choose the correct answer :

(1) The strong nuclear forces are characterized by all of the following, except that they .....

a. have a great power.

b. work at short range.

c. are different according to nucleons charges.

d. do not depend on the nucleons charges.

(2) The mass of the combined nucleons is called ..... of the nucleus.

a. theoretical mass

b. mass number

c. actual mass

d. calculated mass

(3) The ratio of N : Z in the stable light nuclei is .....

a. 1 : 2

b. 1 : 1

c. 2 : 1

d. 5 : 1

(4) If the proton is converted into neutron, ... is emitted.

a. γ

b. α

c. β^+

d. β^-

(5) Positron is considered as an electron of .....

a. neutral charge.

b. negative charge.

c. positive charge.

d. undefined charge.

(6) The charge of down quark equals .....

a. $-\frac{1}{3}$ e

b. -1 e

c. $+\frac{2}{3}$ e

d. 0

(7) Which of the following represents the quarks composing the proton ? .....

a. uuu

b. uud

c. udd

d. ddd

(8) Which of the following particles is composed of three quarks which are ddu ? .....

a. The proton.

b. The neutron.

c. The electron.

d. α – particle.

2 Give reasons for :

(1) The nucleus is stable, although it has electrostatic repulsive forces between the positive protons inside the nucleus.

(2) Nucleus of calcium atom $^{40}_{20}Ca$ is stable.

(3) The actual mass of the atom's nucleus is less than the sum of the masses of the nucleons forming it.

(4) The nuclei of the elements located on the left side of the belt of stability are mostly unstable.

(5) The nuclei of the elements located on the right side of the belt of stability are unstable.

(6) The nuclei located above the belt of stability emit alpha particles.

(7) The proton carries a positive charge, whereas the neutron is electrically neutral.

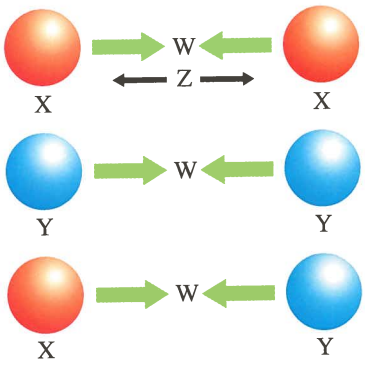
Open book questions

Answered

Multiple choice questions

1 Which of the following choices represents correctly the letters W , X , Y and Z ? .....

Choices	W	X	Y	Z
(a)	Strong nuclear forces	Proton	Proton	Electrostatic forces
(b)	Electrostatic forces	Neutron	Neutron	Strong nuclear forces
(c)	Strong nuclear forces	Proton	Neutron	Electrostatic forces
(d)	Electrostatic forces	Proton	Neutron	Strong nuclear forces



2 Electrostatic repulsive forces are present and effective in all the nuclei of atoms of elements, except .....

(a) hydrogen. (b) helium. (c) oxygen. (d) sodium.

3 Which of the following statements represents the relation between the mass of the nucleons and the mass of the nucleus ? Mass of free nucleons is .....

(a) larger than that of the nucleus in case of heavy nuclei only.
(b) larger than that of the nucleus in case of light nuclei only.
(c) less than that of the nucleus.
(d) larger than that of the nucleus.

4 Nuclear binding energy is equivalent to the amount of energy .....

(a) required to convert binded nucleons to free protons and neutrons.
(b) required to convert binded nucleons to free protons and electrons.
(c) released when a neutron position in energy levels changes.
(d) released when an electron position in energy levels changes.

5 By knowing the data illustrated in the opposite table.. What is the correct relation which is used in calculating the loss in mass of the nucleus constituents of the element (S) atom ? .....

Protium atomic mass	m_H
Neutron mass	m_n
Atomic mass of the element (S)	m_S

(a) $\Delta m = (Z \times m_H) - (N \times m_n) + m_S$
(b) $\Delta m = (Z \times m_H) + (N \times m_n) - m_S$
(c) $\Delta m = (Z \times m_H) + (N \times m_n) + m_S$
(d) $\Delta m = m_S - (Z \times m_H) - (N \times m_n)$

6 Which of the following laws used to calculate the total nuclear binding energy E ? .....

(a) $E = m\,g\,h$ (b) $E = \frac{1}{2} m\,V^2$

(c) $E = \Delta m\,c^2$ (d) $E = \frac{BE}{A}$

7 When the nuclear binding energy per nucleon is high, so it means that the nucleus of this isotope .....

(a) is completely unstable. (b) is very stable.

(c) contains a small number of electrons. (d) has high $\frac{N}{Z}$ value.

8 Maximum number of protons which can be found in a stable nucleus is .....

(a) 50 (b) 82

(c) 84 (d) 92

9 Which of the following choices represents the heaviest stable nucleus and the number of the neutrons in it ? .....

Choices	(a)	(b)	(c)	(d)
The nucleus	Carbon $^{12}_{6}C$	Uranium $^{235}_{92}U$	Lead $^{208}_{82}Pb$	Lead $^{208}_{82}Pb$
Number of the neutrons	6	143	126	208

10 Among the nuclei which lie at the left side of the belt of stability is .....

(a) $^{4}_{2}He$ (b) $^{14}_{6}C$ (c) $^{16}_{8}O$ (d) $^{17}_{9}F$

11 Among the nuclei which lie at the right side of the belt of stability is .....

(a) $^{38}_{19}K$ (b) $^{35}_{19}K$ (c) $^{40}_{20}Ca$ (d) $^{40}_{19}K$

12 Which of the following has similar properties to that of the electron ? .....

(a) Alpha particle. (b) Beta particle. (c) Gamma ray. (d) X-ray.

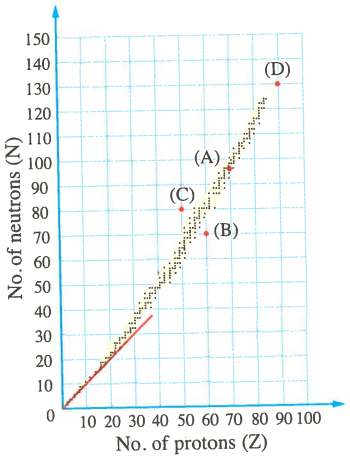
13 Which of the following contains 4 nucleons ? .....

(a) Alpha particle. (b) Beta particle. (c) Gamma ray. (d) Positron.

14 The elements in which Z is less than 20, their $\frac{N}{Z}$ ratio is .....

(a) 0.5 (b) 0.8 (c) 1 (d) 1.3

15 **In the opposite figure :**



1- What is the symbol which refers to a nucleus of a stable element ? .....

(a) (A) (b) (B)

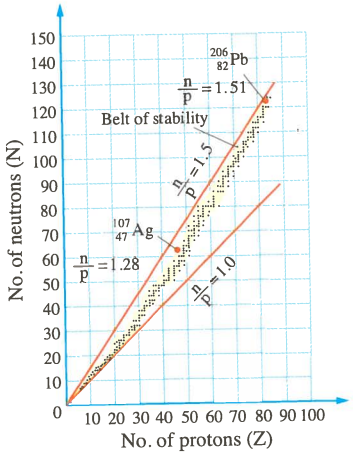
(c) (C) (d) (D)

2- What is the symbol that refers to the nucleus of the element which emits beta particle to be stable ? .....

(a) (A) (b) (B)

(c) (C) (d) (D)

16 **In the opposite figure which represents the belt of stability :**



1- Why does calcium –35 emit positron ? .....

(a) Because it lies above the right side of the belt of stability.

(b) Because it lies down the right side of the belt of stability.

(c) Because its $\frac{N}{Z}$ ratio is high.

(d) Because its number of neutrons is very high.

2- What is the nuclear reaction which the nucleus of $^{70}_{30}Zn$ would undergo ? .....

(a) Emitting beta particle. (b) Losing 2 electrons.

(c) Nuclear fusion. (d) Emitting positron.

17 **A nucleus lies at the upper left side of the belt of stability can decrease its ratio of (neutrons : protons) by** .....

(a) emitting gamma ray only. (b) emitting positron only.

(c) emitting beta only. (d) emitting beta and positron together.

18 **Which of the following statements is correct to describe a neutron ?**

It is composed of .....

(a) a number of down quarks equals the number of up quarks.

(b) a number of down quarks which is double the number of up quarks.

(c) a number of down quarks which is half the number of up quarks.

(d) a number of down quarks which is four times as the number of up quarks.

19 Which of the following represents the number of quarks in the nucleus of tritium isotope ? .....

Choices	(a)	(b)	(c)	(d)
No. of up quarks	4	5	5	7
No. of down quarks	5	4	7	5

Essay questions and problems

Nuclear binding energy

20 If you know that the actual mass of deuterium ($^{2}_{1}H$) = 2.014102 u, mass of proton = 1.00728 u and mass of neutron = 1.00866 u
Calculate the binding energy of deuterium in MeV

21 **Knowing that :** A = 6 , Z = 3 , masses of proton and neutron are 1.00728 u and 1.00866 u respectively and its actual mass = 6.015 u
Calculate the nuclear binding energy (in MeV) in the nucleus of lithium (Li) atom.

22 If the difference between the sum of the masses of the free nucleons and that of the binded nucleons in the nucleus of iron atom $^{56}_{26}Fe$ is 0.5 u, **calculate the nuclear binding energy** in the nucleus of iron atom in million electron volts.

23 If you know that the mass defect in the nucleus of ($^{14}_{7}N$) isotope = 0.105 u, and that of ($^{15}_{7}N$) isotope = 0.115 u, **calculate the nuclear binding energy** in the nucleus of each of them, **then illustrate** which of them is more stable, **and why ?**

Transformed mass

24 **Calculate the transformed mass** to bind the constituents of the nucleus of helium atom ($^{4}_{2}He$), **knowing that** the nuclear binding energy per nucleon in it equals 7.070945 MeV

Actual mass

25 **Calculate the actual mass of** the nucleus of $^{12}_{6}C$ atom, **knowing that :**
* Nuclear binding energy of each nucleon in carbon atom nucleus = 7.42007 MeV
* Mass of each proton and neutron = 1.00728 u, 1.00866 u respectively.

26 **Calculate the mass of** ($^{24}_{12}Mg$) nucleus after binding its constituents , **since :**
BE = 192.717 MeV , mass of proton = 1.00728 u and mass of neutron = 1.00866 u

Theoretical mass

27 **Calculate the theoretical mass** of a nucleus of nitrogen isotope, **since :**

* Its BE = 90.8656 MeV
* Its actual mass = 13.0057 u

28 **Calculate the mass of the free protons and neutrons** in the nucleus of one of cobalt isotopes, **knowing that** its actual mass = 60.93244 u and BE = 521.788 MeV

29 **If you know that :**

* The actual mass of the nucleus of element ^{96}X = 95.889 u
* The nuclear binding energy = 824.3074 MeV
* The mass of neutrons = 55.4763 u
* The mass of the neutron = 1.00866 u

Calculate :

(1) The theoretical mass of the nucleus of that element.

(2) The atomic number of the element.

Mass number

30 **Calculate the mass number** of an isotope of an element whose nuclear binding energy (BE) is 342 MeV and the nuclear binding energy per nucleon in its nucleus is 8.55 MeV

31 **Calculate the number of neutrons** in the nucleus of an element, **knowing that** its BE =186.03 MeV, binding energy per nucleon = 6.89 MeV and its valence third energy level (M) in its atom contains 3 electrons.

32 **Which** of these two unstable isotopes emits an alpha particle ?

Explain.

- $^{241}_{95}Am$
- $^{28}_{13}Al$

33 **Mention the name of the element which is produced by :**

(1) Emitting a positron from oxygen –15 atom nucleus.

(2) Emitting a beta particle from carbon –14 atom nucleus.

"In terms of the data shown in the following table".

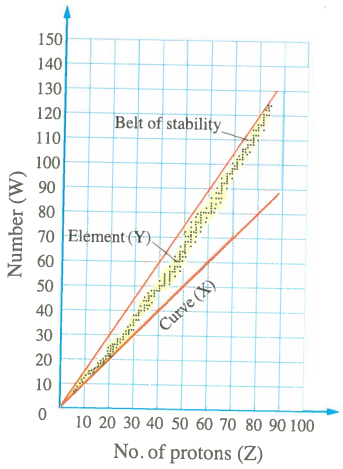
Element	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine
Atomic number	4	5	6	7	8	9

34 **Emission of β^+-particle from the nucleus of element (X) atom and its conversion into ($^{23}_{11}Na$) atom nucleus :**

(1) What is the location of element (X) relating to the belt of stability ?

(2) What is the similarity **and** the difference between β^- and β^+ particles ?

35 **The opposite figure represents the belt of stability of the elements :**

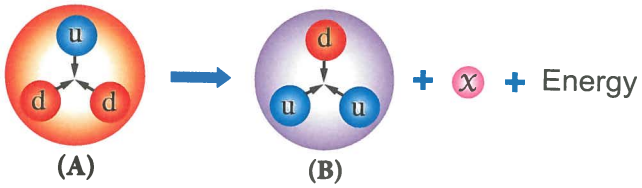


(1) Does (W) represent the number of neutrons or the mass number of the element ?

(2) What is the value $\frac{N}{Z}$ for the elements which are located on the curve (X) ?

(3) Is element (Y) an isotope of $^{132}_{47}Ag$ or $^{107}_{47}Ag$? Mention two reasons to affirm your choice.

36 **In the following figure :**



(1) What do the figures (A) and (B) represent ?

Calculate the electrical charge of each of them.

(2) What is the charge of particle ($\mathcal{X}$) ?

37 **What is the number** of up quarks in the nucleus of the isotope $^{17}_{8}O$?

New types of questions ?

Answered

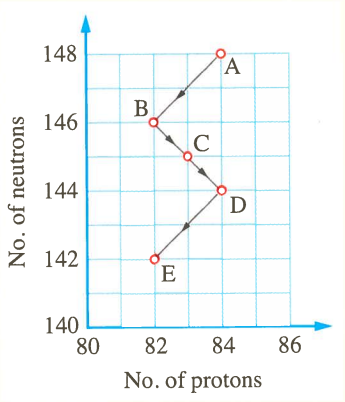
Choosing two out of five choices questions :

1 What are the two types of emissions which are considered as nucleus electrons ? .....

(a) Positron. (b) Alpha particle. (c) Beta particle.

(d) Gamma ray. (e) X–ray.

2 The opposite figure represents a series of nuclear reactions ..
What are the two choices which represent two isotopes for one element in this series ? .....



(a) A and B (b) A and D

(c) B and C (d) C and D

(e) B and E

3 The actual mass of chlorine isotope $^{37}_{17}Cl$ equals 36.966 u, the mass of a proton equals 1.00728 u and that of a neutron equals 1.00866 u
What are the two correct choices among the following ? .....

(a) The theoretical mass of the protons in Cl–37 nucleus = 20.1732 u

(b) The theoretical mass of the neutrons in Cl–37 nucleus = 17.12376 u

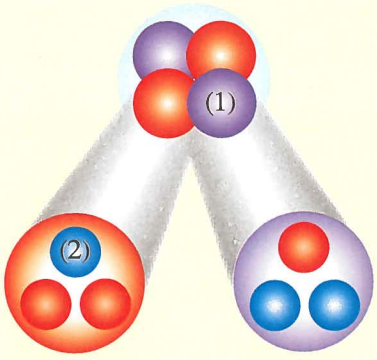
(c) Mass defect of the nucleus components = 0.331 u

(d) Nuclear binding energy = 30.723 MeV

(e) Binding energy per nucleon = 8.3 MeV

The sketch questions :

4 The opposite figure illustrates the composition of the quarks in helium $^{4}_{2}He$ nucleus..
Choose from the following list what is suitable for each of (1) and (2) :



s	p	n
b	d	u

- (1) refers to .....
- (2) refers to .....

Unit 5

Chapter Two

Lesson 1

From Radioactivity and nuclear reactions

Until Before nuclear transformation

Nuclear Reactions

- **Nuclear reactions are different from chemical reactions...**

  Since **nuclear reactions** include a change in the composition of the nuclei and formation of nuclei of new elements atoms.

  Whereas, **chemical reactions** occur between the atoms of the reactant elements through the electrons of their outermost energy levels, and no change occurs to the nuclei of these atoms.

- **The nuclear reactions can be classified into four types, which are :**

  First **Natural transmutation (transformation) of elements (Natural radioactivity).**

  Second **Nuclear transformation (elemental transmutation).**

  Third **Nuclear fission reactions.**

  Fourth **Nuclear fusion reactions.**

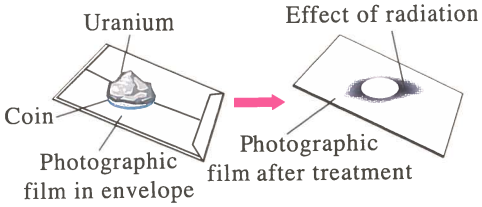
First Natural transmutation of elements

Discovery of radioactivity phenomenon

- In 1896, the scientist Henri Becquerel discovered - coincidently - a kind of invisible radiations produced from one of the uranium compounds, leading to the formation of a shadow on a sensitive photographic film.
- In 1898 Marie Curie named this phenomenon by Radioactivity.

Marie Curie

- Researchers paid their attention to know the nature of these emitted rays and compare their properties by the following two methods, **which are :**
  - Testing the ability of rays to penetrate substances.
  - Testing the deviation of rays by the effect of both the magnetic and electric fields.



Radiations from uranium ***penetrate the paper, but don't penetrate*** *the metallic objects*

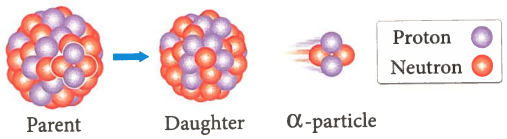
- The experiments inferred that there are three different radiations :
  1. **Alpha radiation (α).**
  2. **Beta radiation (β^-).**
  3. **Gamma rays (γ).**

1 Alpha radiation (α–particles)

- Alpha particle (α) is the nucleus of helium atom (2 protons + 2 neutrons), and its symbol is ^4_2He
- The emission of an α-particle from the nucleus of a radioactive element atom leads to the formation of a new element which has an atomic number (Z) less than the original element by 2 and a mass number (A) smaller by 4

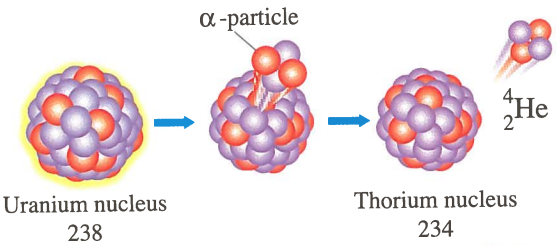
Note

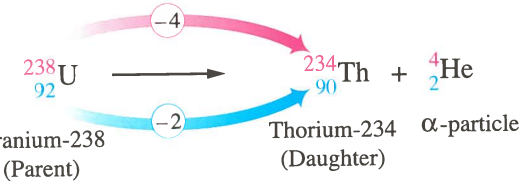
Alpha particle is different from helium atom, although they both have the symbol ^4_2He, because alpha particle is positively charged, while helium atom is neutral.



Emission of an α-particle from an unstable nucleus

Application **Emission of α-particle from the nucleus of the radioactive uranium –238 :**

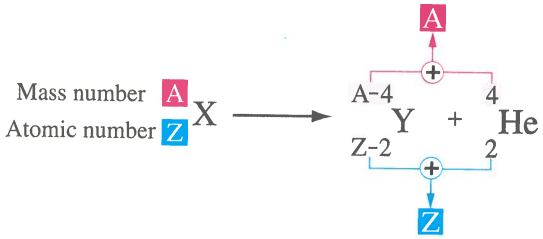




Emission of α–particle from an unstable uranium nucleus

- **It is noticed that :**
  - Mass number (A) of the parent nucleus = The sum of the mass numbers of the daughter nucleus and the alpha particle.
  - Atomic number (Z) of the parent nucleus = The sum of the atomic numbers of the daughter nucleus and the alpha particle.

- **The nuclear equation is balanced,** because the sum of the atomic numbers and the mass numbers of each of the reactants and the products are equal.



Example

Write the nuclear equation which describes the loss of α-particle from the nucleus of radium isotope $^{220}_{88}Ra$ to form radon isotope (Rn).

Solution

$$^{220}_{88}Ra \longrightarrow {}^{216}_{86}Rn + {}^{4}_{2}He$$

Radium-220 — Radon-216 — α-particle

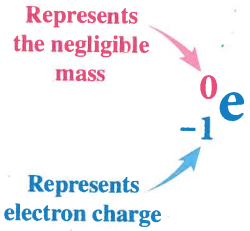
2 Beta radiation (β^-–particle)

- Beta particle β^- is called the nucleus electron, since they are particles that carry the characteristics of electrons in terms of mass, charge and speed.

For illustration

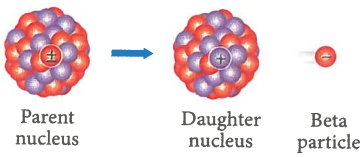
Mass of the electron = 5.49×10^{-4} u
Charge of the electron = 1.6×10^{-19} C

- The mass of beta particles is negligible, due to its very small mass compared to the atomic mass unit (u).



- Beta particle can be symbolized by $^{0}_{-1}e$, because $_{-1}e$ means that its charge is equivalent to the negative charge unit (electron charge), and 0 means that its mass is negligible compared to the masses of both the proton and the neutron.

- Emission of β^--particle from a nucleus of a radioactive element is accompanied by elemental transmutation to form a new element nucleus whose atomic number is greater by one than the parent nucleus, while its mass number remains the same, where beta particle ($^{0}_{-1}e$) is produced from the transformation of a neutron to a proton.

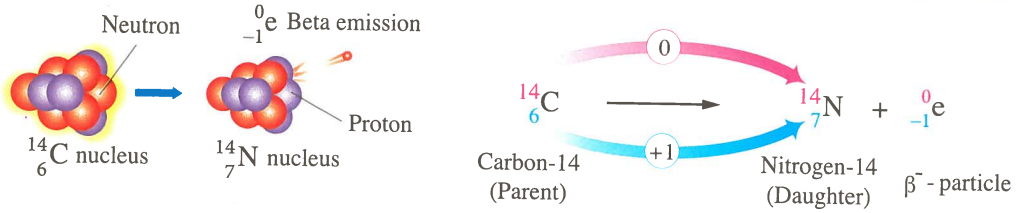


Emission of β^--particle from an unstable nucleus

$$^{1}_{0}n \longrightarrow {}^{1}_{1}H + {}^{0}_{-1}e$$

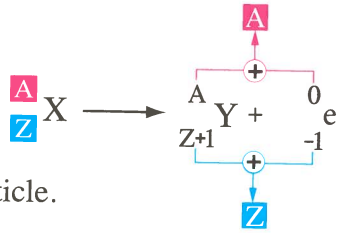
Neutron — Proton — Beta particle

Application Describe the emission of β^-–particle from radioactive carbon–14



Emission of β^--particle from unstable carbon nucleus

- **It is noticed that :**
  - Mass number (A) of parent nucleus
    = Sum of the mass numbers of daughter nucleus and beta particle.
  - Atomic number (Z) of parent nucleus
    = Sum of the atomic numbers of daughter nucleus and beta particle.



Examples

1 **Write the nuclear equation that describes** the emission of β^--particle from sodium isotope $^{24}_{11}Na$ to form magnesium Mg

Solution

$$^{24}_{11}Na \longrightarrow {}^{24}_{12}Mg + {}^{0}_{-1}e$$

Sodium-24 — Magnesium-24 — β^- - particle

2 **Write the atomic number (Z) and mass number (A)** of a radioactive element that is converted to a stable element whose atomic number is 82 and its mass number is 206 after losing 5 alpha and 4 beta particles.

Solution

$$^{A}_{Z}X \longrightarrow {}^{206}_{82}Y + 5\,{}^{4}_{2}He + 4\,{}^{0}_{-1}e$$

$A = 206 + (5 \times 4) + (4 \times 0) =$ 226 (mass number)

$Z = 82 + (5 \times 2) + (4 \times -1) =$ 88 (atomic number)

3 **Deduce the numbers of alpha particles and beta particles** which are emitted during the transformation of uranium $^{238}_{92}U$ to lead $^{206}_{82}Pb$

Solution

$$^{238}_{92}U \longrightarrow {}^{206}_{82}Pb + X\,{}^{4}_{2}He + Y\,{}^{0}_{-1}e$$

$238 = 206 + (X \times 4) + (Y \times 0)$

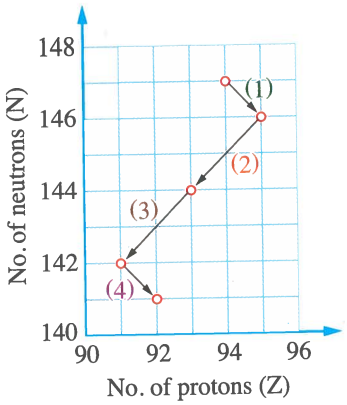
$= 206 + 4X$ $\quad \therefore X =$ 8 (number of alpha particles)

$92 = 82 + (X \times 2) + (Y \times -1)$

$= 82 + (8 \times 2) - Y$ $\quad \therefore Y =$ 6 (number of beta particles)

4 **From the opposite figure, replace the numbers from (1) to (4)** by four nuclear reactions indicating a natural radioactivity, **knowing that** the symbols and the atomic numbers of the radioactive elements are as in the following table :

Element	Pu	Am	Np	U	Pa
Z	94	95	93	92	91



Solution

(1) $^{241}_{94}Pu \longrightarrow {}^{241}_{95}Am + {}^{0}_{-1}e$

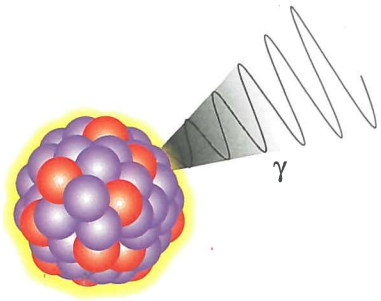
(2) $^{241}_{95}Am \longrightarrow {}^{237}_{93}Np + {}^{4}_{2}He$

(3) $^{237}_{93}Np \longrightarrow {}^{233}_{91}Pa + {}^{4}_{2}He$

(4) $^{233}_{91}Pa \longrightarrow {}^{233}_{92}U + {}^{0}_{-1}e$

3 Gamma rays (γ)

- Properties of gamma rays (γ) :
  - They are electromagnetic waves (photons), **i.e** they have no mass and no charge.
  - They have very short wavelength.
  - Their speed equals the speed of light.
  - They have a high frequency.
  - Their photons have high energy, due to their **high** frequency and **short** wavelength.



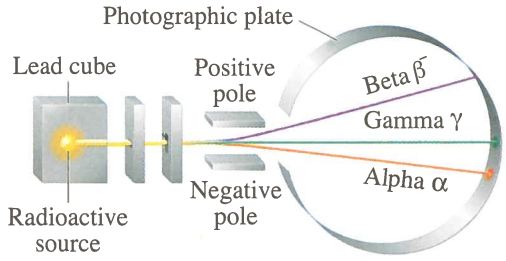
Emission of γ-rays from a nucleus of a radioactive element

- Emission of γ-rays isn't accompanied by change in atomic or mass numbers, **this is attributed to** the nature of γ-rays, they are photons (electromagnetic waves) that have no mass and no charge.

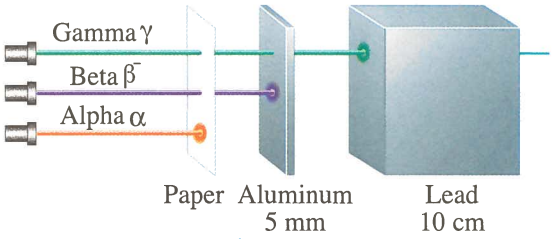
The effect of the emissions of each alpha, beta and gamma can be summarized in the following table :

Emission / Its effect on	Alpha (α) $^{4}_{2}He$	Beta (β^-) $^{0}_{-1}e$	Gamma (γ)
No. of protons (P)	decreases by 2	increases by 1	no change
Atomic number (Z)	decreases by 2	increases by 1	no change
No. of neutrons (n)	decreases by 2	decreases by 1	no change
Mass number (A)	decreases by 4	no change	no change

Comparison between : Alpha, Beta and Gamma radiations



Effect of the electric and magnetic fields



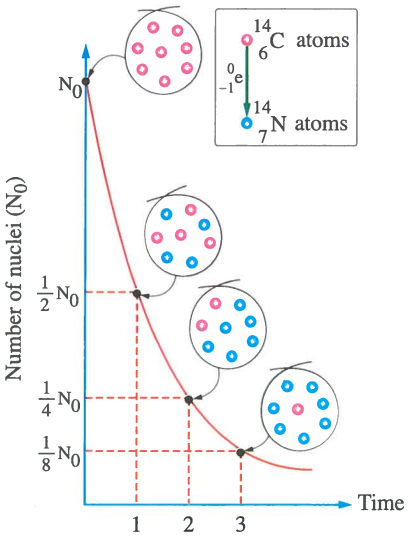
Penetration power

Points of comparison	Alpha emission	Beta emission	Gamma emission
Symbol	α	β^-	γ
Nature	Nucleus of ^4_2He atom (2 protons + 2 neutrons)	Nucleus electron $^0_{-1}e$	Photons (electromagnetic waves)
Mass	4 times as the mass of the proton	(1/1800) of the mass of the proton	No mass
Charge	(+ve) charged particles	(–ve) charged particles	No charge
Ability to penetrate	Weak (can't penetrate a paper of a book)	Medium (can't penetrate an aluminum plate of 5 mm thickness)	Very powerful (passing through a few centimeters thick lead slice, but its intensity decreases during the penetration)
The ability to ionize the medium passing through	Very high	High	Low
Effect of the electric field	Deviated towards the negative pole (small deviation)	Deviated towards the positive pole (significant deviation)	Not affected
Effect of the magnetic field	Affected (small deviation)	Affected (significant deviation)	Not affected

Half-life ($t_{\frac{1}{2}}$)

The scientists concluded through studying of the radioactivity that :

- The activity of the radioactive elements **decreases** with time.
- The number of the nuclei of the atoms of each radioactive element disintegrates to the half of its original number after a certain period of time, they called this period of time **Half-life time** ($t_{\frac{1}{2}}$), and the half-life ($t_{\frac{1}{2}}$) is repeated at equal periods of time, the half-life ($t_{\frac{1}{2}}$) is constant for each radioactive element, but it differs from one radioactive element to another, where it might be seconds or millions of years.



Relation between the number of the decayed nuclei and time

Original amount of a radioactive element		Time (Zero)
$\frac{1}{2}$ Disintegrated	$\frac{1}{2}$ Remained	After passing 1st half-life
$\frac{3}{4}$ Disintegrated	$\frac{1}{4}$	After passing 2nd half-life
$\frac{7}{8}$ Disintegrated	$\frac{1}{8}$	After passing 3rd half-life

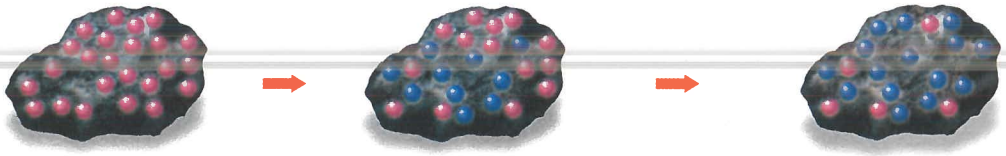
⇩

and so on

The half-life ($t_{\frac{1}{2}}$) is calculated from the following relation :

$$\text{Half-life } (t_{\frac{1}{2}}) = \frac{\text{Total decay time (t)}}{\text{Number of periods (D)}}$$

- The half-life ($t_{\frac{1}{2}}$) phenomenon can be used to determine the age of rocks and mummies by using the half-life ($t_{\frac{1}{2}}$) of **carbon-14 isotope**.

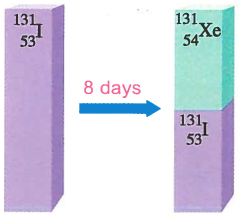


Recent rock — *Rock after a short period of time* — *Rock after a long period of time*

What is meant by

The half-life of iodine – 131 = 8 days ?

This means that the time required for decaying half the number of the atoms nuclei of the radioactive iodine – 131 element equals 8 days.



Number of atoms nuclei of iodine –131 decreases to its half amount after 8 days

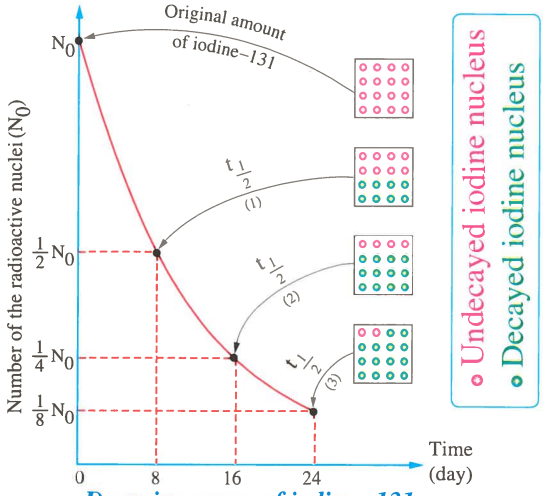
Application Radioactive decaying of iodine – 131

If you have 100 g of iodine – 131, so the mass decreases to the half after 8 days, as shown in the opposite graph and the following table :

Time (days)	Remained mass (g)
0	100
0 + 8 = 8	100 ÷ 2 = 50
8 + 8 = 16	50 ÷ 2 = 25
16 + 8 = 24	25 ÷ 2 = 12.5

⇓

and so on



Decaying curve of iodine –131

Examples

1 **Calculate the half-life $(t_{\frac{1}{2}})$** of a radioactive element, knowing that a sample of 12 g of it converted to 1.5 g after passing 45 days.

Solution

12 g $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 6 g $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 3 g $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 1.5 g

∵ Number of periods (D) = 3

$\therefore t_{\frac{1}{2}} = \frac{t}{D} = \frac{45}{3} =$ 15 days

2 A sample of wood contains 9×10^{16} nuclei of carbon – 14 atoms whose half-life is 5600 years, **what is the number of the nuclei of carbon – 14** which remains present in the wood sample after 16800 years ?

Solution

$D = \frac{t}{t_{\frac{1}{2}}} = \frac{16800}{5600} = 3$

9×10^{16} nuclei $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 4.5×10^{16} nuclei $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 2.25×10^{16} nuclei $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 1.125×10^{16} nuclei

∴ Number of remaining nuclei = 1.125×10^{16} nuclei

3 **Calculate the half-life ($t_{\frac{1}{2}}$)** of a radioactive element, where 75% of its nuclei decayed after 12 min

Solution

∵ 75% of nuclei decayed. ∴ The percentage of remaining nuclei = 100% – 75% = 25%

100% $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 50% $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 25%

∵ D = 2 ∴ $t_{\frac{1}{2}} = \frac{t}{D} = \frac{12}{2} =$ 6 min

4 **A sample of a radioactive element whose number of atoms is 4.8×10^{12}, $\frac{7}{8}$ of the mass of its atoms disintegrated after 9 months,**
Calculate : (1) Number of remaining atoms of this element.
(2) The half-life of this element.

Solution

(1) ∵ $\frac{7}{8}$ of the mass disintegrated.
∴ The remaining mass = $1 - \frac{7}{8} = \frac{1}{8}$ of the original mass.
∴ Number of remaining atoms = $\frac{1}{8} \times 4.8 \times 10^{12} = 0.6 \times 10^{12}$ atoms

(2) 4.8×10^{12} atoms $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 2.4×10^{12} atoms $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1.2×10^{12} atoms $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 0.6×10^{12} atoms

∵ D = 3 ∴ $t_{\frac{1}{2}} = \frac{t}{D} = \frac{9}{3} =$ 3 months

5 **Calculate the original mass** of a radioactive element that after 2.5 days, 0.0625 g of it remained, **knowing that** its half-life is 0.5 day.

Solution

$D = \frac{t}{t_{\frac{1}{2}}} = \frac{2.5}{0.5} = 5$

0.0625 g $\xrightarrow[(5)]{t_{\frac{1}{2}}}$ 0.125 g $\xrightarrow[(4)]{t_{\frac{1}{2}}}$ 0.25 g $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 0.5 g $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1 g $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 2 g

∴ The original mass = 2 g

6 **What is the time** which is required for the disintegration of 53.125% of the nuclei of a radioactive element whose half-life is 32 min ?

Solution

32 min $\xrightarrow{\text{required for}}$ 50%

? min $\longrightarrow$ 53.125%

$\therefore$ Time required $= \frac{53.125 \times 32}{50} =$ 34 min

7 **How many atoms** of 1 mol of the radioactive thorium–234 would remain after 72.3 days, if its half-life is 24.1 days ?

Solution

$D = \frac{t}{t_{\frac{1}{2}}} = \frac{72.3}{24.1} = 3$

$\because$ Number of atoms of 1 mol of any element under the standard conditions

= Avogadro's number = 6.02×10^{23} atoms

6.02×10^{23} atoms $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 3.01×10^{23} atoms $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1.505×10^{23} atoms $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 0.7525×10^{23} atoms

$\therefore$ Number of remaining atoms = 0.7525×10^{23} atoms

8 **The opposite table shows the decaying process of 80 g of a radioactive element during 8 days :**

Mass (g)	80	40	20	10	5
Time (days)	0	2	4	6	8

(1) Calculate the half-life ($t_{\frac{1}{2}}$) of the element.

(2) Calculate the mass of the decayed nuclei after 6 days.

(3) Calculate the time required for the mass of this element to reach 2.5 g

Solution

(1) $\because$ The original mass (80 g) became 40 g after 2 days.

$\therefore t_{\frac{1}{2}} =$ 2 days

(2) $\because$ The mass of the radioactive element after 6 days = 10 g

$\therefore$ The mass of the decayed nuclei = 80 – 10 = 70 g

(3) 80 g $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 40 g $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 20 g $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 10 g $\xrightarrow[(4)]{t_{\frac{1}{2}}}$ 5 g $\xrightarrow[(5)]{t_{\frac{1}{2}}}$ 2.5 g

$\because D = 5$ $\therefore t = t_{\frac{1}{2}} \times D = 2 \times 5 =$ 10 days

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Complete the following equations :

(1) $^{238}_{92}U \longrightarrow \cdots\cdots + {}^{4}_{2}He$

(2) $^{14}_{6}C \longrightarrow \cdots\cdots + {}^{0}_{-1}e$

2 Choose the correct answer :

(1) Which of the following doesn't apply to α-particles ? .....

a. It is a nucleus of helium atom.

b. It is strongly capable of ionizing the air.

c. It has a higher ability to penetrate the opaque objects.

d. It deviates in magnetic field.

(2) Which of the following particles its mass is the smallest ? .....

a. α-particle. b. Electron. c. Neutron. d. Proton.

(3) Emission of α-particle from the nucleus of $^{B}_{A}X$ can be expressed by the equation .....

a. $^{B}_{A}X \longrightarrow {}^{B-4}_{A-2}Y + {}^{4}_{2}He$

b. $^{B}_{A}X \longrightarrow {}^{B+4}_{A+2}Y + {}^{4}_{2}He$

c. $^{B}_{A}X \longrightarrow {}^{B-2}_{A-4}Y + {}^{4}_{2}He$

d. $^{B}_{A}X \longrightarrow {}^{A-2}_{B-2}Y + {}^{4}_{2}He$

(4) Which of the following choices yields a beta particle when it is transformed to a proton ? .....

a. $^{1}_{1}H$ b. $^{4}_{2}He$ c. $^{1}_{0}n$ d. e^{-}

(5) Which of the following properties is applied to γ-rays ? .....

a. They have positive charge.

b. They have negative charge.

c. They are electrons.

d. They are electromagnetic waves.

3 Give reasons for :

(1) Emission of α-particle is accompanied by an elemental transformation.

(2) The nuclear equation is balanced.

(3) β^--particle is called electron of the nucleus.

(4) The increase in the atomic number by 1 and no changes in the mass number when β^--particle is lost.

(5) No changes in atomic number or mass number when γ-rays are emitted.

(6) γ-rays are not affected by electric and magnetic fields.

4 What is meant by that the half life time of sodium –24 is 14.8 h ?

Steady

Open book questions

Answered

Multiple choice questions

Natural transformation of elements

1 Which of these equations represents a natural radioactivity ? .....

(a) $14C + Ca_3(PO_4)_2 \longrightarrow 3CaC_2 + 2P + 8CO$

(b) ${}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n + Energy$

(c) ${}^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{14}_{6}C + {}^{1}_{1}H$

(d) ${}^{218}_{84}Po \longrightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$

2 The atom of uranium –238 is .....

(a) stable and absorbs alpha particles spontaneously.

(b) stable and emits alpha particles spontaneously.

(c) unstable and absorbs alpha particles spontaneously.

(d) unstable and emits alpha particles spontaneously.

3 In the opposite nuclear reaction : ${}^{241}_{95}Am \longrightarrow {}^{233}_{91}Pa + 2X$

What is the particle X ? .....

(a) Alpha. (b) Beta. (c) Neutron. (d) Positron.

4 Which of the following choices represents the two particles which almost have the same mass ? .....

(a) Alpha particle and beta particle. (b) Alpha particle and proton.

(c) Neutron and positron. (d) Neutron and proton.

5 Element L is transformed into element M, according to the opposite nuclear equation : ${}^{A}_{Z}L \longrightarrow {}^{A}_{Z+1}M + X$

What is the particle X ? .....

(a) Alpha particle. (b) Beta particle.

(c) Neutron. (d) Nucleus of helium atom.

6 What is the number of the electrons in the valence shell of the element whose nucleus is produced from emitting a beta particle from the nucleus of the atom of sodium isotope ${}^{24}_{11}Na$?.....

(a) 1 electron. (b) 2 electrons. (c) 6 electrons. (d) 7 electrons.

7 What is the number of the nucleons in the nucleus of the element produced from emitting a beta particle from the nucleus of a radioactive element contains 128 nucleons ? .....

(a) 124 (b) 127 (c) 128 (d) 129

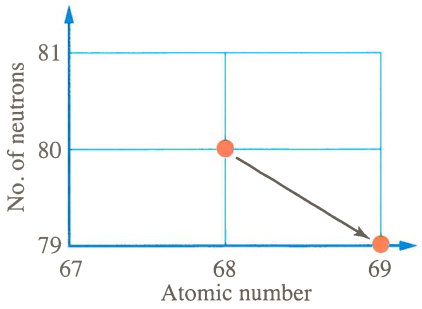
8 $^{53}_{24}Cr$ is produced from the emission of a beta particle from .....

(a) $^{53}_{25}Mn$ (b) $^{54}_{24}Cr$ (c) $^{52}_{24}Cr$ (d) $^{53}_{23}V$

9 Plutonium –238 is characterized by the emission of an alpha particle producing the nucleus of .....

(a) plutonium –234 (b) curium –242 (c) uranium –234 (d) thorium –230

10 What are the atomic number and the mass number of the isotope produced from the nuclear reaction illustrated in the opposite figure ? .....



Choices	(a)	(b)	(c)	(d)
Atomic number	69	68	69	68
Mass number	80	80	148	148

11 Which of the following choices represents the product $\mathcal{X}$ in the equation : $^{236}_{92}U \longrightarrow 4\,^{1}_{0}n + {}^{136}_{53}I + \mathcal{X}$

(a) $^{98}_{41}Nb$ (b) $^{96}_{38}Sr$ (c) $^{96}_{39}Y$ (d) $^{98}_{40}Zr$

12 In the opposite nuclear reaction : $^{42}_{19}K \longrightarrow M + {}^{0}_{-1}e$

What is the formula of the oxide of the produced element ? .....

(a) MO_2 (b) M_2O (c) M_2O_3 (d) MO

13 The symbol of a nucleus produced from the decay of the nucleus of $^{A}_{Z}X$ element atom by emission of one α-particle then one β^--particle is .....

(a) $^{A-4}_{Z}X$ (b) $^{A-1}_{Z-4}Y$ (c) $^{A-4}_{Z-1}Y$ (d) $^{A-4}_{Z-2}Y$

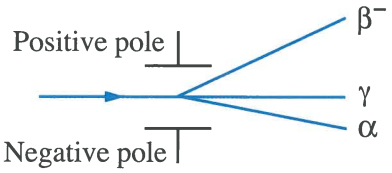
14 On emission of one β^--particle and γ-rays from the nucleus of a radioactive element $^{238}_{92}A$, ... isotope is formed.

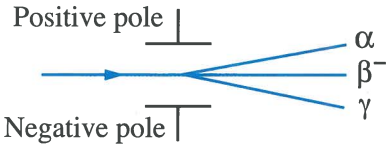
(a) $^{239}_{92}B$ (b) $^{239}_{92}A$ (c) $^{238}_{93}B$ (d) $^{238}_{93}A$

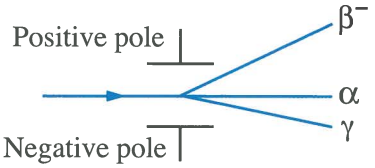
15 When $^{238}_{92}U$ loses 1 α-particle, then 2 β^--particles and γ-rays, it is transformed into .....

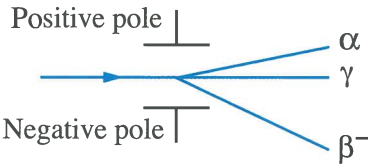
(a) $^{236}_{92}U$ (b) $^{238}_{90}Th$ (c) $^{234}_{91}Pa$ (d) $^{234}_{92}U$

16 **A beam of particles is emitted from a radioactive element and passes through two poles of an electric field.. Which of the following choices expresses the correct path of the particles ?** .....

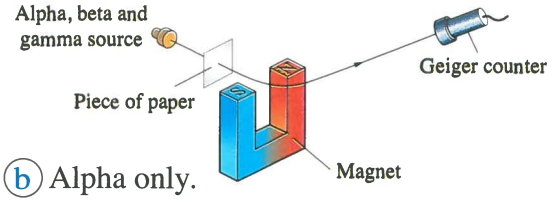
(a)


(b)


(c)


(d)


17 **In the opposite figure : What is (are) the radiation(s) which can be received by the Geiger counter ?** .....

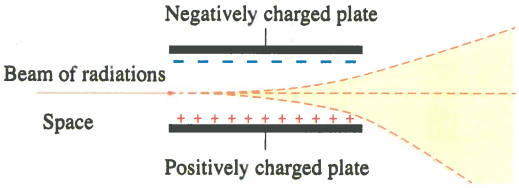


(a) Alpha and beta together.
(b) Alpha only.
(c) Beta and gamma together.
(d) Beta only.

18 **Which of the following choices represents the ascending graduation in the energy of the nuclear emissions ?** .....

(a) $\alpha < \gamma < \beta^-$ (b) $\beta^- < \alpha < \gamma$ (c) $\alpha < \beta^- < \gamma$ (d) $\beta^- < \gamma < \alpha$

19 **Scientists use the characteristic deviations of different types of radiations when they pass through an electric field to differentiate between them, so if a beam of radiations is passed in an electric field (as in the figure), some will deviate upwards, some downwards and some of them will not deviate at all.. Which of the following choices is correct ?** .....



Choices	(a)	(b)	(c)	(d)
Gamma	Does not deviate	Does not deviate	Deviates downwards	Does not deviate
Neutron	Deviates upwards	Deviates upwards	Deviates downwards	Does not deviate
Proton	Deviates downwards	Does not deviate	Deviates upwards	Deviates upwards

Half – life

20 On putting a radioactive source in front of Geiger counter, the rate of counting decreases from 4000 CPM (counts per minute) to 500 CPM within 72 min
What is the half-life of this radioactive element ? .....

(a) 8 min (b) 9 min (c) 18 min (d) 24 min

21 The opposite table shows the number of emissions per second emitted from a radioactive element during 60 min
What is the half-life of this element ? .....

(a) 10 min
(b) 20 min
(c) 40 min
(d) 60 min

Time (min)	Number of emissions per second
0	800
10	560
20	400
30	280
40	200
50	140
60	100

22 After passing 48 hours for a sample of a radioactive element, $\frac{1}{16}$ of it remained unchanged.. What is the half-life of this element ? .....

(a) 3 h (b) 9.6 h (c) 12 h (d) 24 h

23 A sample of wood contains 9×10^{16} nuclei of carbon-14 atoms and its half-life equals 5600 years.. What is the number of carbon-14 nuclei which remained in the wood sample after passing 16800 years ? .....

(a) 1.125×10^{2} nuclei. (b) 1.125×10^{16} nuclei.
(c) 2.25×10^{16} nuclei. (d) 4.5×10^{16} nuclei.

24 A sample of a radioactive element its mass is 4.8 g, if this element has a half-life $\left(t_{\frac{1}{2}}\right)$ = 2 years.. What is the mass of the nuclei of this element which decayed after 8 years ? .....

(a) 0.3 g (b) 2.4 g (c) 4.2 g (d) 4.5 g

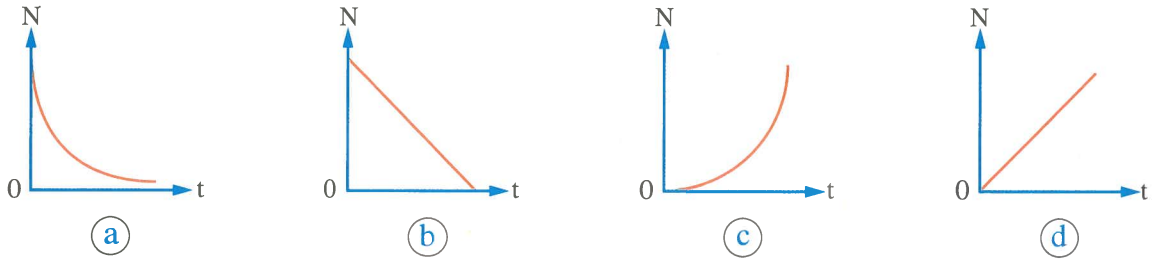
25 The half-life of a radioactive element = 2 days, the number of its atoms' nuclei decreases into $\frac{1}{8}$ of its original mass after .....

(a) 4 days. (b) 6 days. (c) 8 days. (d) 16 days.

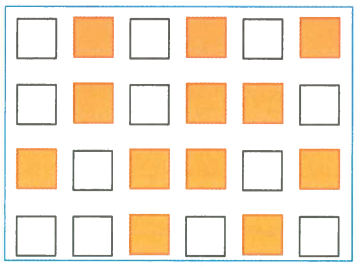
26 The half life time of the radioactive iodine is 8 days, if there is a sample of it contains x atoms.. What is the number of the atoms of it remained without decaying after 24 days ? .....

(a) $\frac{1}{2}x$ (b) $\frac{1}{4}x$ (c) $\frac{1}{8}x$ (d) $\frac{1}{16}x$

27 Which of the following graphical figures represents the number of radioactive nuclei (N) and the time of their disintegration (t) ? .....



28 The opposite figure represents a sample of a radioactive element after passing one half-life time for it.. What is the number of squares that should be shaded after another half-life time ? .....



Radioactive substance before decaying

Substance produced from decaying

(a) Zero

(b) 3

(c) 6

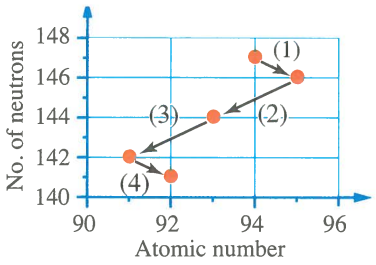
(d) 12

Questions marked by this mark are for the superiors and their ideas are explained in the answers

Essay questions

Natural transmutation of elements

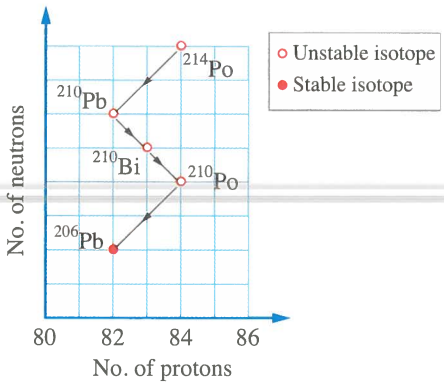
29 **In the opposite figure, mention the number of arrows** which express(es) the nuclear reaction(s) which is (are) accompanied by emission of one alpha particle, **with giving reason.**



30 **The opposite figure shows the number of protons and neutrons of some isotopes formed during nuclear reactions :**

(1) Calculate number of neutrons in nucleus of ^{210}Po

(2) What is the change occurred in the number of protons and neutrons on the transformation of ^{210}Pb nucleus to ^{210}Bi nucleus ?
Mention the type of the nuclear reaction.



31 **Write the atomic and mass numbers of element X in the following equations :**

(1) $^{226}_{88}Ra \longrightarrow X + {}^{4}_{2}He$

(2) $X \longrightarrow {}^{140}_{58}Ce + {}^{4}_{2}He$

(3) $^{95}_{36}Kr \longrightarrow X + {}^{0}_{-1}e$

(4) $X \longrightarrow {}^{233}_{92}U + {}^{0}_{-1}e$

(5) $X \longrightarrow {}^{234}_{92}U + {}^{4}_{2}He + 2\,{}^{0}_{-1}e$

32 **Write the nuclear equations** that express the nuclear reactions shown in the following decaying serial :

$$^{232}_{90}Th \xrightarrow{(1)} {}^{228}_{88}Ra \xrightarrow{(2)} {}^{228}_{89}Ac \xrightarrow{(3)} {}^{228}_{90}Th \xrightarrow{(4)} {}^{224}_{88}Ra$$

Problems of calculating the emission of alpha and beta particles

33 **What is the change that occurs** in the atomic number and mass number of a radioactive element whose atomic number is 88 and its mass number is 226, when it loses 5 α-particles then 4 β^--particles ?

34 **Conclude the number** of alpha particles and beta particles emitted during the transformation of uranium $^{238}_{92}U$ to lead $^{206}_{82}Pb$

35 **What is the number of each of** the nucleons and the neutrons found in the nucleus of the element (X) atom which is transformed into the element $^{23}_{11}Na$ by emitting a beta particle from the nucleus of its atom ?

36 A radioactive element $^{A}_{Z}X$ is transformed into an element $^{A_1}_{Z_1}Y$ after losing 2 α-particles and 4 β^--particles , **find the relation between** (A , A_1) and (Z , Z_1).
Is it transformed into another element ?

37 **Write** the atomic and mass numbers of the elements (A $\longrightarrow$ D) in the following series of a natural radioactive decaying process.
What is the relation between the nuclei of each of D **and** $^{238}_{92}U$?

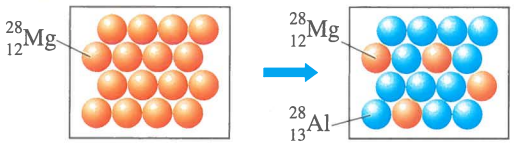
$$^{238}_{92}U \xrightarrow{-\alpha} A \xrightarrow{-\beta^-} B \xrightarrow{-\alpha} C \xrightarrow{-3\,\beta^-} D$$

Half-life ($t_{\frac{1}{2}}$)

38 87.5% of a radioactive element is decayed after 2 months,
calculate the half-life of this element.

39 A radioactive substance decays to its half amount after 5 day..
Will it completely decay after 10 days ? **Explain your answer.**

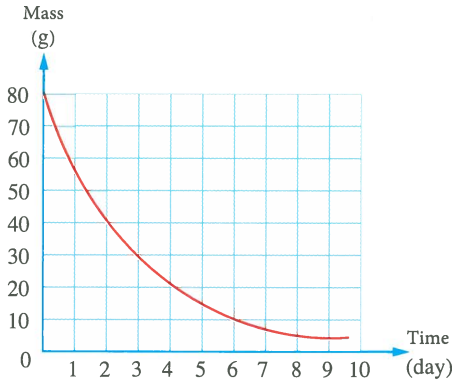
40 **The opposite figure expresses the elemental transmutation of the nuclei of the radioactive magnesium-28 atoms to nuclei of radioactive aluminum-28 atoms :**



(1) What is the type of emission which leads to this elemental transmutation ? With giving reason.

(2) What is the number of half-life times which passed over the original sample after a certain period of time ?

41 **The opposite graph illustrates the relation between mass and time of the decay of a radioactive element, assisted by this figure, answer the following questions :**

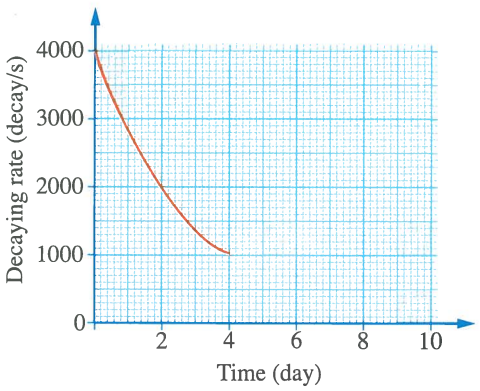


(1) What is the half-life $\left(t_{\frac{1}{2}}\right)$ of the element ?

(2) What is the amount of the remaining mass after 4 days ?

(3) What is the mass of the decayed element after 6 days ?

42 **The opposite graph represents** the decaying rate of a radioactive source by time, **calculate** the decaying rate in the eighth day (in decay per second).

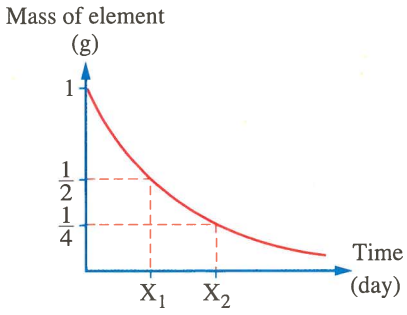


Problems of calculating the total time of decay

43 **Calculate the time required** for decaying $\frac{1}{4}$ of the mass of a radioactive element whose mass = 32 g, and its half-life is 3 years.

44 **Calculate the date of death of one of the pharaohs**, knowing that his mummy which contains carbon-14 isotope recorded 7.65 decay/min, and the decaying rate of carbon-14 in nature and in the living organisms equals 15.3 decay/min, and its half-life equals 5700 years.

45 **The opposite figure represents the relation between** the mass of the element and the time taken to be transformed into a stable element, if the original mass = 1 g and half-life = 20 days. **What is the value of X_1 and X_2 ?**



Problems of calculating the masses of radioactive elements

46 A radioactive element whose mass equals 64 g and its half-life equals 4 months.. **calculate the mass remained** after passing one year.

47 **1 g of radioactive phosphorus is left for 28 h and 0.25 g of it remained, Calculate :**

(1) Half-life of radioactive phosphorus.

(2) Mass of phosphorus after another 28 hours.

48 A sample of a radioactive element whose number of atoms equals 4.8×10^{12} atoms, $\frac{7}{8}$ of its mass decayed after 9 months.. **Calculate the number of atoms remained and the half-life of this element.**

49 **How many atoms remained** from 1 mol of radioactive thorium-234 after 72.3 days at the standard conditions, knowing that its half-life = 24.1 days ?

50 **The mass of a radioactive element was measured at periodic intervals and was recorded in the following table :**

Time (min)	0	25	50	75	100
Mass (g)	2	1.5	1	0.75	0.5

(1) Draw a graph to represent the relation between mass and time.

(2) Calculate the half-life of this element.

(3) Calculate the remaining mass after 150 min.

51 A sample of a radioactive element, containing 4.8×10^{12} atoms remained after passing 4 years, **calculate number of atoms' nuclei** in this sample.. knowing that its half-life equals 1 year.

New types of questions ?

Answered

Choosing two out of five choices questions :

1 A nucleus of a radioactive element emits an alpha particle.. What are the two choices which represent the produced nucleus ? This nucleus contains .....

(a) 144 nucleons. (b) 144 neutrons. (c) 90 protons.

(d) 236 nucleons. (e) 236 neutrons.

2 What are the two radiations which are affected by the magnetic field ? .....

(a) Alpha. (b) Gamma. (c) Neutron.

(d) Beta. (e) Deuteron.

3 Bismuth –214 decays yielding one of polonium isotopes according to the opposite incomplete equation : $^{214}_{W}Bi \longrightarrow {}^{X}_{Y}B + n\,{}^{Z}_{84}Po$

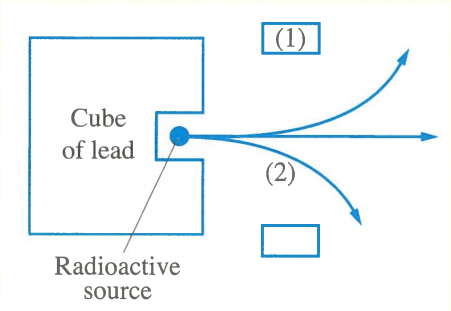
What are the two choices which represent the unknown values in this equation correctly ? .....

(a) W = 82 (b) X = –1 (c) Y = 0

(d) Z = 214 (e) n = –1

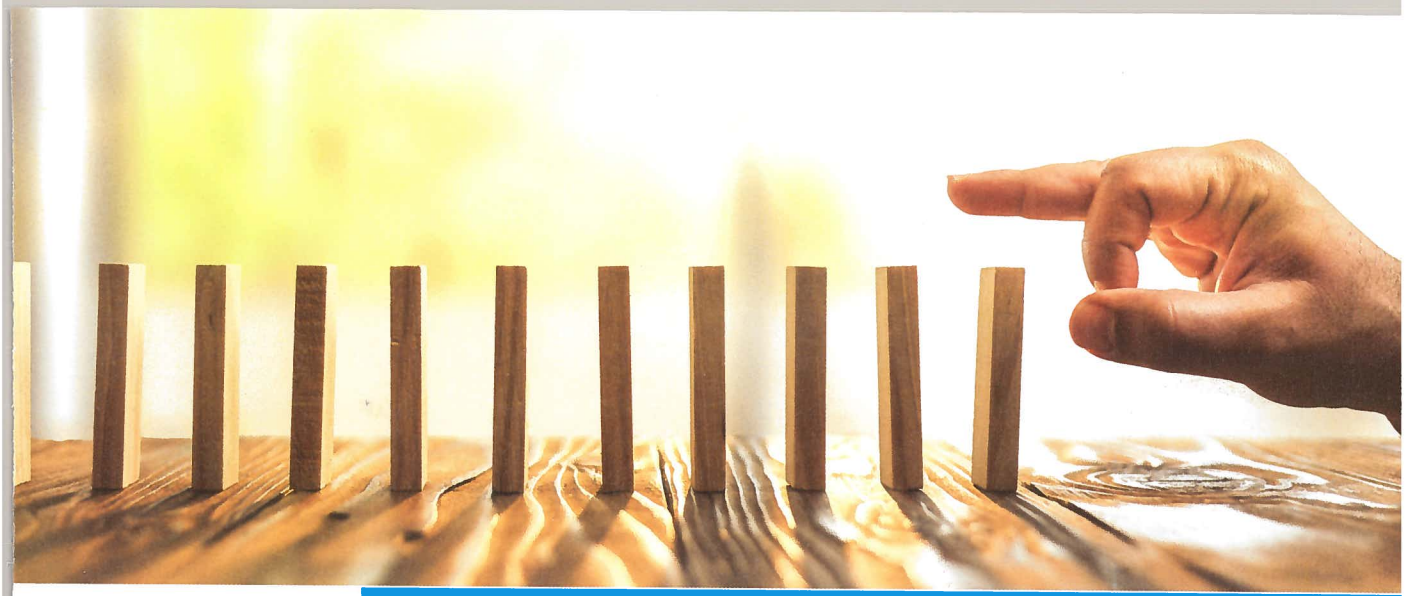
The sketch questions :

4 The opposite figure represents three types of rays passing through an electric field.. Choose from the following list what is suitable for each of (1) and (2) :



Alpha particle	Gamma rays	Positive pole
Beta particle	Neutron	Negative pole

- (1) represents .....
- (2) represents .....



Unit 5

Chapter Two

Lesson 2

From Nuclear transformation

Until The end of the chapter

Second Nuclear transformation (elemental transmutation)

- **Nuclear transformation reactions** are nuclear reactions in which the nucleus of an element (called target) is bombarded with an accelerated particle called projectile (bomb) to transform the target into a new nucleus having new chemical and physical properties.

- **The following table shows some examples for the bombs :**

Bomb	Alpha	Proton	Deuteron	Neutron
Symbol	$^{4}_{2}He$	$^{1}_{1}H$	$^{2}_{1}H$	$^{1}_{0}n$

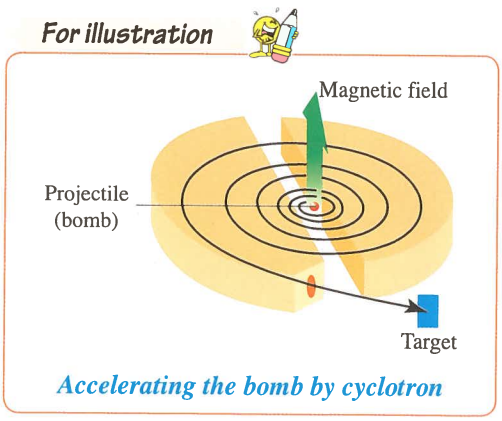
- The projectiles (bombs) can be accelerated by using devices called nuclear accelerators,

like :

– The Van de Graaf accelerator.

– The cyclotron accelerator.

For illustration

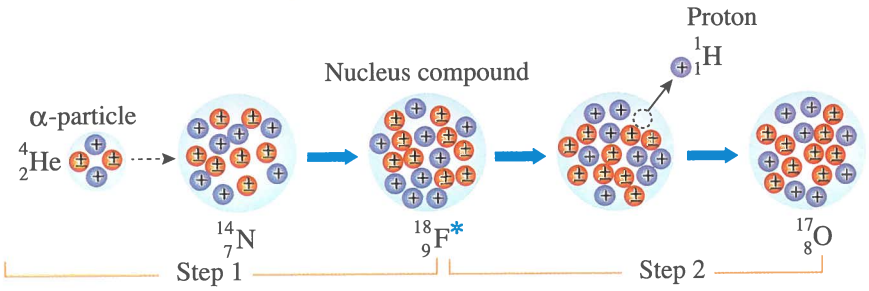


Accelerating the bomb by cyclotron

Applications

1 Using α-particle (^4_2He) as a bomb

- The first scientist who performed an artificial nuclear reaction was **Rutherford** in 1919,
  where : – α-particles were used as a bomb.
  – Nitrogen gas as a target, **as shown in the following :**



The sign * indicates that the nucleus of this element is unstable and decays rapidly

Rutherford reaction

*** Step (1) :**

The α-particle (bomb) merges with the nucleus of the nitrogen-14 atom to form the nucleus of fluorine-18 isotope (unstable) and is called the nucleus compound.
(it is unstable and with high energy).

$$^{14}_7N + {}^4_2He \longrightarrow {}^{18}_9F^*$$

Nitrogen-14 (Target) | Alpha particle (Bomb) | Fluorine-18 (Nucleus compound)

*** Step (2) :**

The unstable fluorine-18 nucleus gets rid of the excess energy through emitting an accelerated proton and transforms into a nucleus of stable oxygen-17 isotope within 10^{-9} sec.

$$^{18}_9F^* \longrightarrow {}^{17}_8O + {}^1_1H$$

Summation

$$^{14}_7N + {}^4_2He \longrightarrow {}^{17}_8O + {}^1_1H$$

Nitrogen-14 | α-particle | Oxygen-17 | Proton

Equation of the transformation of nitrogen-14 into oxygen-17

2 Using proton (^1_1H) as a bomb

- **Bombarding the nucleus of aluminum-27 with a proton bomb :**

*** Step (1)**

$$^{27}_{13}Al + {}^1_1H \longrightarrow {}^{28}_{14}Si^*$$

Aluminum-27 | Proton | Silicon-28

*** Step (2)**

$$^{28}_{14}Si^* \longrightarrow {}^{24}_{12}Mg + {}^4_2He$$

Summation

$$^{27}_{13}Al + {}^1_1H \longrightarrow {}^{24}_{12}Mg + {}^4_2He$$

Aluminum-27 | Proton | Magnesium-24 | α-particle

Equation of the transformation of aluminum-27 into magnesium-24

3 Using deuteron ($^{2}_{1}H$) as a bomb

- **Bombarding the nucleus of magnesium $^{26}_{12}Mg$ with a deuteron bomb :**

* **Step (1)**

$$^{26}_{12}Mg + {}^{2}_{1}H \longrightarrow {}^{28}_{13}Al^{*}$$

Magnesium-26 — Deuteron — Aluminum-28

* **Step (2)**

$$^{28}_{13}Al^{*} \longrightarrow {}^{24}_{11}Na + {}^{4}_{2}He$$

Summation

$$^{26}_{12}Mg + {}^{2}_{1}H \longrightarrow {}^{24}_{11}Na + {}^{4}_{2}He$$

Magnesium-26 — Deuteron — Sodium-24 — α-particle

Equation of the transformation of magnesium-26 into sodium-24

4 Using neutron ($^{1}_{0}n$) as a bomb

- **Bombarding the nucleus of lithium-6 with a neutron bomb :**

$$^{6}_{3}Li + {}^{1}_{0}n \longrightarrow {}^{3}_{1}H + {}^{4}_{2}He$$

Lithium-6 — Neutron — Tritium-3 — α-particle

Equation of the transformation of lithium-6 into tritium

- **The neutron ($^{1}_{0}n$) is one of the most favorable bombs,** because it has a neutral charge and it doesn't meet a repulsion with the electrons surrounding the nucleus. So it doesn't require a high energy to enter the nucleus.

Balancing the nuclear equations

- During balancing the nuclear equations, the following laws must be verified :
  - Charge conservation law.
  - Mass (Matter) conservation law.

- **Charge conservation law implies that :**

Sum of the reactants atomic numbers (Z) = Sum of the products atomic numbers (Z)

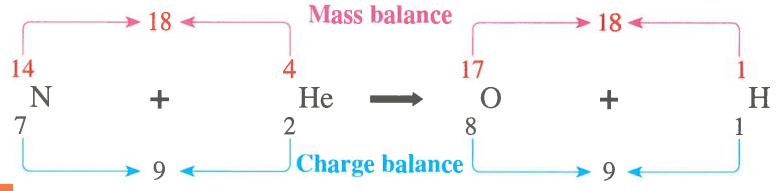
"Left side of nuclear equation" "Right side of nuclear equation"

- **Mass (Matter) conservation law implies that :**

Sum of the reactants mass numbers (A) = Sum of the products mass numbers (A)

"Left side of nuclear equation" "Right side of nuclear equation"

Application Balancing the charge and the mass in the reaction of bombarding the nucleus of nitrogen-14 with an α-particle $^{4}_{2}He$



Example

Predict the atomic number (Z) and the mass number (A) of the daughter element (X) of the following two nuclear equations, (on the basis of your knowledge about the laws of charge and mass conservation).

(1) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{160}_{62}Sm + {}^{A}_{Z}X + 4\,{}^{1}_{0}n$

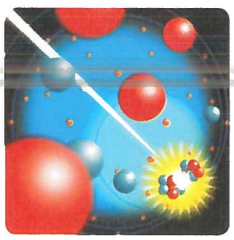
(2) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{102}_{42}Mo + {}^{A}_{Z}X + 2\,{}^{1}_{0}n$

Solution

Applying the laws of conservation of charge and mass	Equation (1)	Equation (2)
The sum of the mass no. of the reactants	235 + 1 = 236	
The sum of the mass no. of the products	160 + A + (4 × 1) = 164 + A	102 + A + (2 × 1) = 104 + A
Mass no. (A) of the daughter element (X)	236 = 164 + A ∴ A = 72	236 = 104 + A ∴ A = 132
The sum of the atomic no. of the reactants	92 + 0 = 92	
The sum of the atomic no. of the products	62 + Z + (4 × 0) = 62 + Z	42 + Z + (2 × 0) = 42 + Z
The atomic no. (Z) of the daughter element (X)	92 = 62 + Z ∴ Z = 30	92 = 42 + Z ∴ Z = 50

Third Nuclear fission reactions

- **Nuclear fission** is the reaction in which a heavy nucleus is bombarded with a light nuclear projectile (bomb) of low kinetic energy causing the fission of the heavy nucleus into two nuclei of close masses, number of neutrons and a huge amount of energy.



Nuclear fission

Application Fission of the nucleus of uranium-235 :

- When the nucleus of uranium-235 atom is bombarded with a slow neutron, it is transformed into unstable uranium-236 (its life time doesn't exceed 10^{-12}s) that is divided into two nuclei (X) and (Y), which are called the fragments of nuclear fission or daughter nuclei, in addition to a number of neutrons according to the mass conservation law.

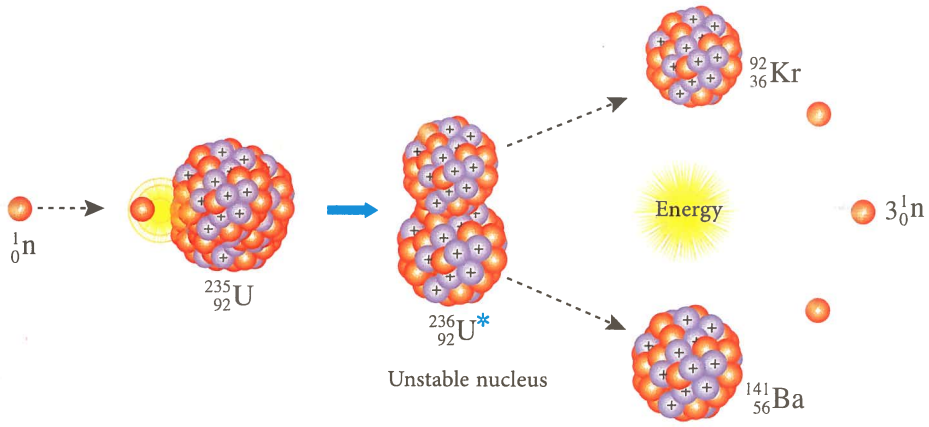
$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow [^{236}_{92}U^{*}] \longrightarrow X + Y + 2 \text{ or } 3\,{}^{1}_{0}n$$

Uranium-235 Neutron Uranium-236 Daughter nuclei

- There are 90 variant nuclei that could be produced from this fission, **the most common** nuclei are barium (Ba) and krypton (Kr) :

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{236}_{92}U^{*} \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$$

Uranium-235 Neutron Uranium-236 Barium-141 Krypton-92



Fission of uranium-235 on its bombardment with a neutron

- **Among the possible reactions also, are :**

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{236}_{92}U^{*} \longrightarrow {}^{139}_{56}Ba + {}^{94}_{36}Kr + 3\,{}^{1}_{0}n$$

Uranium-235 Neutron Uranium-236 Barium-139 Krypton-94

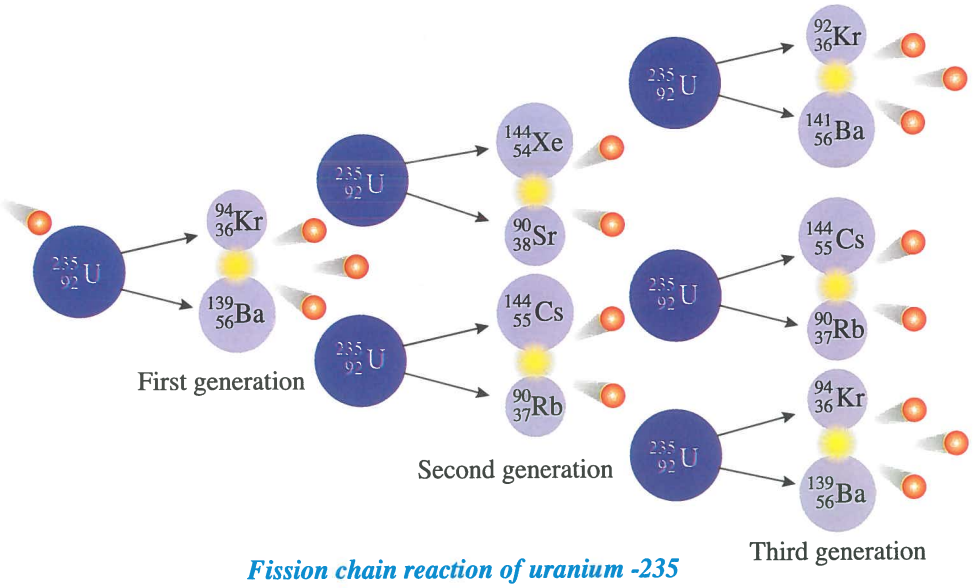
$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{236}_{92}U^{*} \longrightarrow {}^{144}_{54}Xe + {}^{90}_{38}Sr + 2\,{}^{1}_{0}n$$

Uranium-235 Neutron Uranium-236 Xenon-144 Strontium-90

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{236}_{92}U^{*} \longrightarrow {}^{144}_{55}Cs + {}^{90}_{37}Rb + 2\,{}^{1}_{0}n$$

Uranium-235 Neutron Uranium-236 Cesium-144 Rubidium-90

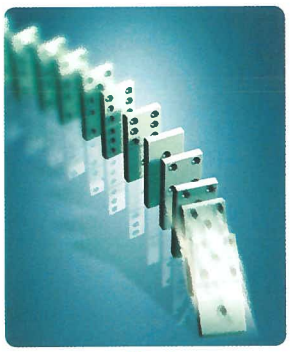
Serial (chain) reaction



Fission chain reaction of uranium -235

- The neutrons produced from the fission reaction act as new projectiles (bombs) that make new similar fission reactions and so they split other nuclei of uranium-235
  So, this reaction is called chain (serial) reaction.

- The chain reaction generates a huge amount of thermal energy, **due to the continuity** of the fission reaction and increasing the number of the produced neutrons.



Perception for the concept of chain reaction

The concept of the nuclear fission reactor

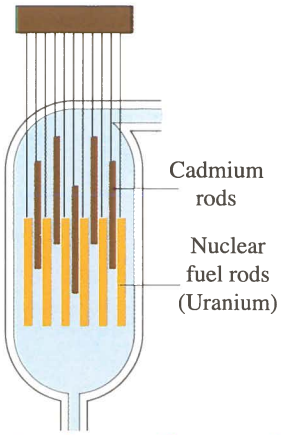
- The nuclear fission reactor is one of the peaceful applications of the chain (serial) nuclear fission reaction and the main reaction is the fission reaction of the nucleus of uranium-235

- The amount of uranium used in the nuclear reactor has a certain volume which is called **the definite (critical) volume**, which is the amount of uranium-235 in which one neutron - in average - from each reaction can start a new nuclear fission reaction, **to ensure** the continuity of the chain reaction in the same slow initial rate to produce energy without an explosion.

☆ The nuclear chain fission should be controlled in the nuclear reactor by absorbing the neutrons **through :**

1 Inserting cadmium control rods between the nuclear fuel rods (uranium-235) :

When these rods are lowered between fuel rods, the chain nuclear reaction begins to slow down as they absorb neutrons, while on raising them the chain nuclear reaction rate increases (an inverse process).

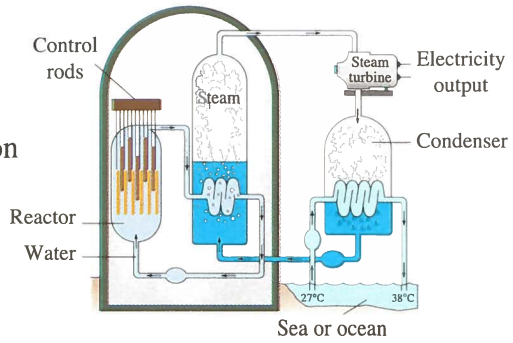


Controlling the rate of nuclear fission reactions by using cadmium control rods

2 Controlling the number of used cadmium control rods :

When the number of cadmium control rods increases, the rate of absorbing neutrons increases. So, the rate of the chain nuclear fission reaction decreases.

☆ The heat energy produced from the nuclear reactions in the nuclear reactor is used in boiling water and using the produced steam to generate electricity by using steam turbines.

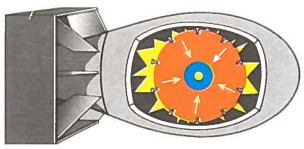


Nuclear reactors are used in producing energy (generating electricity)

"For illustration"

The concept of fission bomb

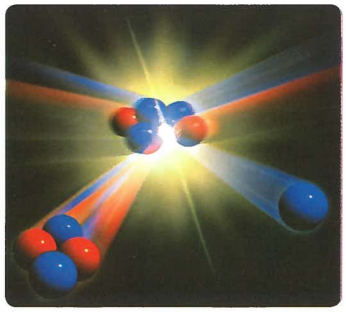
- The nuclear fission bomb is one of the unpeaceful applications of fission reactions.
- In the fission bomb, the amount of uranium-235 is much larger than the critical volume, at which the reaction will continue with an accelerated rate that will lead to an explosion.



Model of the nuclear bomb which was detonated over Nagasaki on August 9, 1945

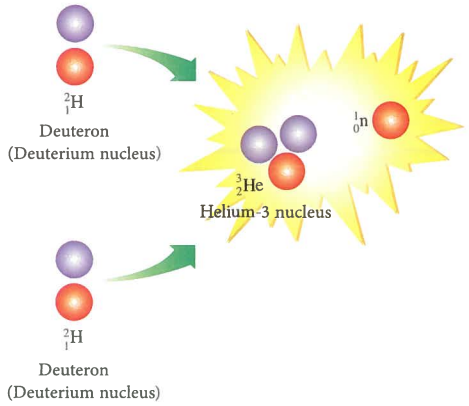
Fourth Nuclear fusion reactions

- **Nuclear fusion** is the fusion of two light nuclei to form a heavier nucleus of a mass smaller than the sum of the masses of the fused nuclei.
- The nuclear fusion reactions are the source of the destructive energy of the hydrogen bomb.

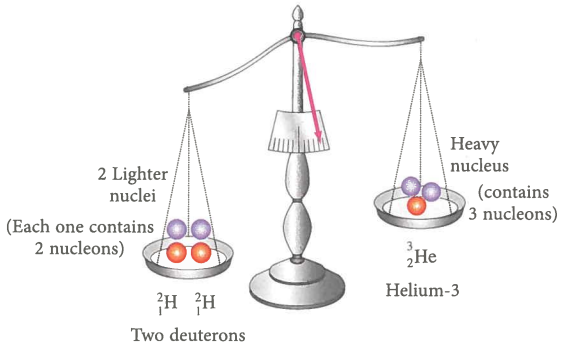


Nuclear fusion

Application Fusion of two deuterons to form helium-3 nucleus :



Fusion of two deuterons



The mass of the produced nucleus is less than the sum of the masses of the fused nuclei

During the fusion of the two deuterons ($^{2}_{1}H$) together, the mass of the produced nucleus is less than the sum of the masses of the fused nuclei, **due to the conversion of** the difference in mass to energy = 3.3 MeV that is liberated during the fusion of these two deuterons.

$$\underset{\text{Deuteron (Deuterium nucleus)}}{^{2}_{1}H} + \underset{\text{Deuteron (Deuterium nucleus)}}{^{2}_{1}H} \longrightarrow \underset{\text{Helium-3}}{^{3}_{2}He} + \underset{\text{Neutron}}{^{1}_{0}n} + 3.3\ \text{MeV}$$

Note

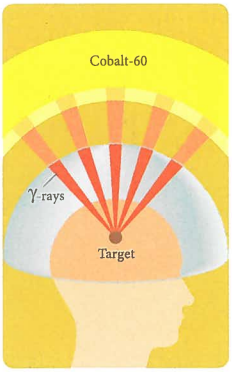
Although the nuclear fusion occurs inside the sun, but it is difficult to be achieved in laboratories, because the nuclear fusion reactions require a high temperature that reaches to rank 10^{7} K, which can't be achieved in laboratories

Compare between the chemical reactions and the nuclear reactions.

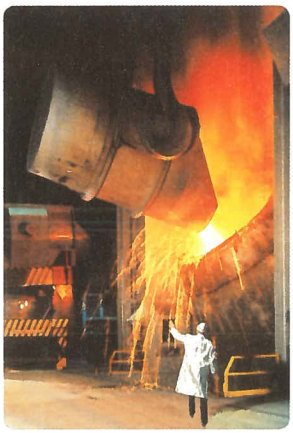
Chemical reactions	Nuclear reactions
Occur between the electrons of the outermost shells of the atom	Occur between the nuclei of the elements through the nucleons of the nucleus
There is no transformation for the element to another one	Almost there is a transformation of an element to another one or its isotope
Isotopes of the same element give the same products	Isotopes of the same element give different products
Accompanied by releasing or absorbing a small amount of energy	Accompanied by releasing a huge amount of energy

Peaceful uses of the radioactive isotopes

Field	Peaceful use
The medical field	• Destroying carcinogenic cells by : - Directing gamma rays (γ) emitted from cobalt-60 or cesium-137 radioactive isotopes to the center of the tumor. - Implanting needles made of radioactive radium-226 isotope in the carcinogenic tumor to destroy it.
The industrial field	• Automation of some production lines such as in pouring of molten steel. In which the source of gamma rays (γ) (cobalt-60 or cesium-137 isotopes) is placed at one of the sides of the pouring machine and a radiations detector which is sensitive to γ-rays is placed on the other side. When the iron mass reaches certain dimensions, the detector can't receive γ-rays and thus the pouring process stops.
The agricultural field	• Creating mutations in embryos and selecting the finest of them **to produce** plants of greater productivity and resistance to diseases by exposing seeds to different dosages of γ-rays. • Sterilization of plants and animals products by using γ-rays, **to preserve** them from spoiling and increase their storage time. • Sterilizing male insects by using γ-rays, **to limit** the spread of agricultural pests.



Using γ-rays to destroy carcinogenic cells

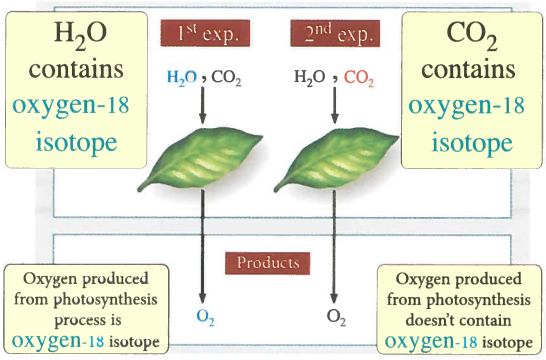


Pouring of molten steel (iron)

(a) (b)

Two samples of strawberry, they were left and exposed to air for 3 days (the first sample (a) is exposed to γ-rays)

The scientific researches field	• Tracing the cycle of some substances in plants by placing radioactive isotopes in the main substances that plants use, then tracing the emissions from these substances to know their cycle in the plant, like inserting water that has radioactive oxygen-18 to the plant and following its track.



To prove that the source of produced oxygen gas in photosynthesis process is water not CO_2
"For illustration"

Harmful effects of nuclear radiations

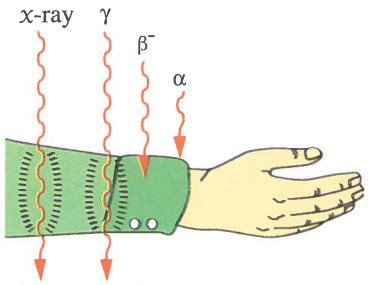
There are two types of radiations :

1 **Ionizing radiations.** **2** **Non-ionizing radiations.**

1 Ionizing radiations

• **Ionizing radiations** *are the radiations that cause changes in the composition of tissues exposed to them.*

• These radiations are called ionizing radiation, **because** when they fall on any object, they collide with the atoms of this object causing their ionization.



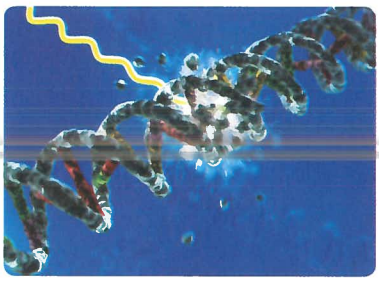
The ability of penetration of ionizing radiations

Examples

• α-radiations. • β^--radiations. • γ-rays. • x-rays.

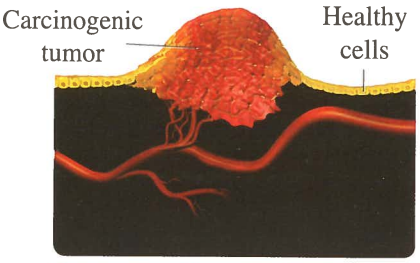
Harms

• The exposure of the cell to the ionizing radiations leads to the ionization of water molecules that represent the larger part of any living cell which leads to the breakage of the chromosomes inside it and causing some genetic deformations.



Breakage of chromosomes by ionizing radiation

- The continuous exposure to the ionizing radiations **leads to :**
  - Preventing or delaying the cell division or increasing the rate of its division, which leads to the formation of carcinogenic tumors.
  - Occurrence of permanent changes in the cell that are genetically transported to the next generations. The result is the birth of new infants that are different from their parents.
  - Death of cells.



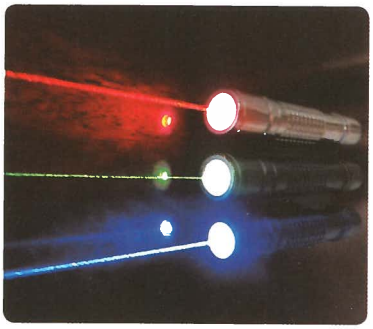
Increasing the rate of cell division leads to carcinogenic tumor

2 Non-ionizing radiations

- **Non-ionizing radiations** *are the radiations that do not cause changes in the composition of tissues that are exposed to them.*

Examples

- Radio waves emitted from cellular phones.
- Microwaves.
- Infrared rays.
- Ultraviolet rays.
- Laser rays.
- Visible rays.



Laser rays

Harms

- The radiations emitted from the cellular towers may cause physiological changes in the nervous system **that appear as :**
  - Headache.
  - Dizziness.
  - Fainting symptoms.

  It might result in amnesia.
- Scientists have agreed that the distance between cellular towers and households must be safe (at least 6 meters).
- The electric and magnetic fields of the radio waves emitted from the cellular phones are dangerous on the body cells and also cause an increase in their temperature, due to the absorption of these rays by the cells.
- Some studies have noted that the use of laptops by placing them on the knees affects fertility.

Rays emitted from cellular towers

Placing laptop on the knees affects fertility

Questions ?

UNIT 5 — Chapter Two — Lesson 2

Ready

Preliminary questions to check the attainment

Answer them yourself

1 Complete the following nuclear equations :

(1) $^{14}_{7}N + \cdots\cdots \longrightarrow \cdots\cdots + {}^{1}_{1}H$

(2) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + \cdots\cdots + \cdots\cdots$

(3) $^{2}_{1}H + {}^{2}_{1}H \longrightarrow \cdots\cdots + \cdots\cdots + 3.3$ MeV

2 Choose the correct answer :

(1) When the nucleus of $^{26}_{12}Mg$ element is bombed with deuteron, the isotope ..... is formed.

a. $^{6}_{3}Li$ b. $^{24}_{11}Na$ c. $^{28}_{14}Si$ d. $^{24}_{12}Mg$

(2) Which of the following elements nuclei when it is bombarded by a neutron, an alpha particle is obtained ? .....

a. Nitrogen-14 b. Aluminum-27 c. Magnesium-26 d. Lithium-6

(3) In the nuclear reactors, controlling the rate of the serial nuclear fission reaction is accomplished by using rods of .....

a. radium. b. thorium. c. cadmium. d. beryllium.

(4) Which of the following nuclear reactions is the source of the destructive energy in the hydrogen bomb ? .....

a. Natural elemental transformation. b. Artificial transformation.

c. Fission. d. Fusion.

(5) One of the isotopes used in the control of industrial production lines is .....

a. radium-226 b. cobalt-60 c. oxygen-18 d. uranium-235

(6) All of these are ionizing radiations, except .....

a. γ-rays. b. X-rays. c. β^{-}-particles. d. infrared rays.

3 Give reasons for :

(1) The neutron is the most favorable bomb.

(2) Stopping the nuclear reaction as the cadmium rods are completely dipped.

(3) The distance between the cellular towers and houses must be at least 6 m

4 Write the atomic and mass numbers for X in the nuclear equations :

(1) $X + {}^{4}_{2}He \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H$

(2) ${}^{27}_{13}Al + {}^{1}_{1}H \longrightarrow X + {}^{4}_{2}He$

Steady

Open book questions

Answered

Multiple choice questions

1 What are the types of the reactions (1) and (2) ? .....

(1) $^{238}_{92}U + ^{1}_{0}n \longrightarrow ^{239}_{93}Np + ^{0}_{-1}e$

(2) $^{37}_{20}Ca \longrightarrow ^{37}_{21}Sc + ^{0}_{-1}e$

Choices	Reaction (1)	Reaction (2)
(a)	Nuclear fusion	Nuclear fission
(b)	Nuclear fission	Natural transmutation
(c)	Nuclear fission	Elemental transmutation
(d)	Elemental transmutation	Natural transmutation

2 On bombarding $^{11}_{5}B$ nucleus with an alpha particle, a new nucleus is formed with emitting a neutron.. Which of the following equations represents this nuclear reaction ? .....

(a) $^{11}_{5}B + ^{1}_{1}H \longrightarrow ^{11}_{6}C + ^{1}_{0}n$

(b) $^{11}_{5}B + ^{2}_{2}He \longrightarrow ^{12}_{7}N + ^{1}_{0}n$

(c) $^{11}_{5}B + ^{4}_{2}He \longrightarrow ^{14}_{6}C + ^{1}_{1}n$

(d) $^{11}_{5}B + ^{4}_{2}He \longrightarrow ^{14}_{7}N + ^{1}_{0}n$

3 On bombarding the nucleus of $^{10}_{5}B$ with a neutron, this results in the formation of an alpha particle and .....

(a) $^{1}_{0}n$ (b) $^{2}_{1}H$ (c) $^{3}_{1}H$ (d) $^{7}_{3}Li$

4 In the nuclear reaction : $^{27}_{13}Al + ^{4}_{2}He \longrightarrow ^{30}_{15}P + X$

What is the product X ? .....

(a) Electron. (b) Neutron. (c) Positron. (d) Proton.

5 In a nuclear reactor, uranium-238 nucleus is bombarded with a deuteron $^{2}_{1}H$, according to the equation : $^{238}_{92}U + ^{2}_{1}H \longrightarrow X + 2^{1}_{0}n$

What is the symbol of the produced isotope X ? .....

(a) $^{238}_{93}Np$ (b) $^{238}_{94}Pu$ (c) $^{240}_{93}Np$ (d) $^{240}_{94}Pu$

6 The following nuclear reaction represents bombarding a uranium-235 nucleus with a slow neutron : $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{154}_{60}Nd + ^{80}_{32}Ge + X$

What does X represent ? .....

(a) 1 neutron. (b) 2 electrons. (c) 2 neutrons. (d) 2 protons.

7 Which of the following equations expresses the probable occurring reaction in the fission nuclear reactor ? .....

(a) $^{14}_{7}N + ^{1}_{0}n \longrightarrow ^{15}_{7}N$

(b) $^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He$

(c) $^{239}_{92}U \longrightarrow ^{95}_{38}Sr + ^{141}_{54}Xe + 3^{1}_{0}n$

(d) $^{46}_{21}Sc \longrightarrow ^{46}_{21}Sc + \gamma$

8 Most of the elements which can undergo nuclear fission have atomic numbers approaching .....

(a) 92 (b) 52 (c) 21 (d) 11

9 In front of you are four probable fission reactions for uranium-235 nucleus.. Which of these reactions is accompanied by the emission of higher number of neutrons ? .....

$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{236}_{92}U$

1 $^{160}_{62}Sm + ^{72}_{30}Zn +$ + Energy

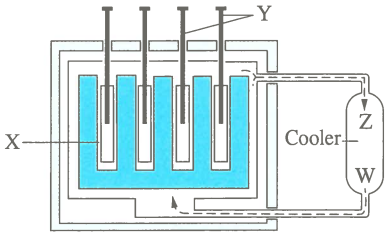
2 $^{141}_{56}Ba + ^{92}_{36}Kr +$ + Energy

3 $^{144}_{54}Xe + ^{90}_{38}Sr +$ + Energy

4 $^{146}_{57}La + ^{87}_{35}Br +$ + Energy

(a) 1 (b) 2 (c) 3 (d) 4

10 The opposite figure represents the composition of a nuclear reactor.. Which of the following sets of choices is correct ? .....



Choices	W	X	Y	Z
(a)	Cold water	Cadmium	Nuclear fuel	Hot water
(b)	Hot water	Cadmium	Nuclear fuel	Cold water
(c)	Cold water	Nuclear fuel	Cadmium	Hot water
(d)	Hot water	Nuclear fuel	Cadmium	Cold water

11 The reaction $^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$ is one of the nuclear reactions.. Which of the following choices represents both the type of this reaction and the conversion occurring in it ? .....

Choices	(a)	(b)	(c)	(d)
Type of the reaction	Fission	Fission	Fusion	Fusion
Occurring conversion	Mass to energy	Energy to mass	Energy to mass	Mass to energy

12 **Which of the following reactions produces greater amount of energy ?** .....

(a) $2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$

(b) ${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n$

(c) $NaOH + HCl \longrightarrow NaCl + H_2O$

(d) ${}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n$

13 **Hydrogen-3 isotope emits spontaneous emissions, unlike the two isotopes hydrogen-2 and hydrogen-1.. Which of the following choices is correct depending on the previous statement ?** .....

Choices	Stable isotope(s)	Used isotope(s) in nuclear fusions
(a)	${}^{1}H$, ${}^{2}H$	${}^{3}H$
(b)	${}^{1}H$, ${}^{2}H$	${}^{1}H$, ${}^{2}H$, ${}^{3}H$
(c)	${}^{3}H$	${}^{1}H$, ${}^{2}H$, ${}^{3}H$
(d)	${}^{3}H$	${}^{1}H$, ${}^{2}H$

14 **Which of the following is common between nuclear fission and nuclear fusion ?** .....

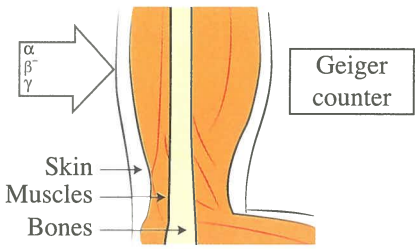
(a) They both are accompanied mostly by releasing neutrons.

(b) They both do not cause harmful effects.

(c) The total mass of the products is higher than that of the reactants.

(d) They both are accompanied by increasing nuclear binding energy per nucleon.

15 **The opposite figure shows the exposure of a person's arm to a beam of alpha, beta and gamma rays, and a Geiger counter is placed on the other side of the arm..**
Why does the reading of the counter become higher after removing the arm ? Because .....



(a) the bones absorb alpha radiation.

(b) the muscles absorb alpha radiation.

(c) the skin absorbs gamma radiation.

(d) the muscles absorb beta radiation.

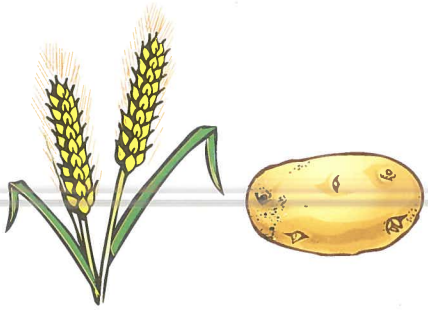
16 **What is the most favorable preservation method for potatoes and wheat ?** .....

(a) Smoking, to protect potatoes from sprout growth, and wheat from insects.

(b) Gamma rays, to protect potatoes from rotting, and wheat from parasites.

(c) Cooling, to stop potatoes growth and to prevent the falling of wheat grains.

(d) Alpha radiation, to protect potatoes from rotting, and wheat from birds.



Wheat *Potato*

Essay questions

17 **The atoms of some elements lose electrons during the chemical reactions and others lose electrons during nuclear reactions.. Illustrate :**

(1) Whence is the electron released in each case ?

(2) What is the change that occurs in the element in each case ?

18 **Write the atomic number and the mass number of the element X in the following nuclear equations which represent the phenomenon of the artificial radioactivity :**

(1) $X + {}^{4}_{2}He \longrightarrow {}^{12}_{6}C + {}^{1}_{0}n$ (2) $X + {}^{1}_{1}H \longrightarrow {}^{29}_{14}Si + \gamma$

19 **Complete the following equations with the proper projectiles :**

(1) ${}^{26}_{12}Mg + \cdots\cdots \longrightarrow {}^{26}_{13}Al + {}^{1}_{0}n$ (2) ${}^{232}_{90}Th + \cdots\cdots \longrightarrow {}^{240}_{96}Cm + 4{}^{1}_{0}n$

20 "When a nucleus of ${}^{235}_{92}U$ is bombarded with a neutron, ${}^{144}_{58}Ce$ and ${}^{90}_{38}Sr$ nuclei are formed with number of electrons and neutrons".

Write the nuclear equation which represents this reaction.

21 **In the opposite nuclear reaction :** ${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{Z}Kr + X{}^{1}_{0}n + Energy$

(1) According to the charge conservation law, what is the required condition for balancing the nuclear equation ?

(2) According to the mass conservation law, what is the required condition for balancing the nuclear equation ?

(3) Calculate the value of each of X and Z

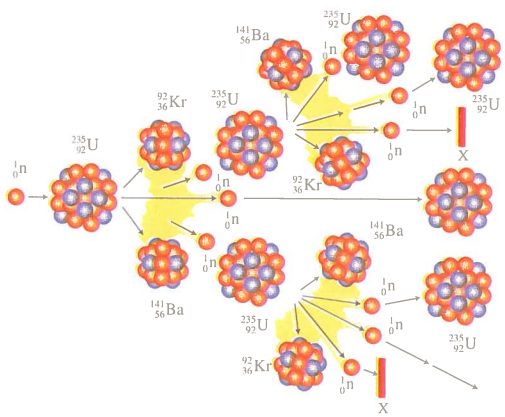
22 The fission of uranium-238 nuclei by bombarding with the accelerated neutrons, forms other neutrons which lose their energy rapidly..

Suggest a reason for not occurring a chain reaction during the fission of uranium-238

23 **The opposite figure represents one of the nuclear reactions :**

(1) What is this type of continuous reaction called ?

(2) What is the use of the constituent X which is found in the fission nuclear reactors but not in the fission nuclear bombs ?



24 **Deuterium nucleus fuses with tritium nucleus forming helium nucleus $^{4}_{2}He$ and another particle :**

(1) Write the nuclear equation which represents this nuclear fusion reaction.

(2) Calculate the amount of energy produced from this fusion estimated in :

1- Million electron volt (MeV).

2- Joule (J).

Knowing that the sum of masses of the fused nuclei = 5.031 u, and that of the produced nucleus = 5.011 u

25 In the light of Hess's law, **conclude the final equation by the indication of the following nuclear equations :**

* $^{1}_{1}H + {}^{12}_{6}C \longrightarrow {}^{13}_{7}N + \gamma$
* $^{13}_{7}N \longrightarrow {}^{13}_{6}C + {}^{0}_{+1}e$
* $^{1}_{1}H + {}^{13}_{6}C \longrightarrow {}^{14}_{7}N + \gamma$
* $^{1}_{1}H + {}^{14}_{7}N \longrightarrow {}^{15}_{8}O + \gamma$
* $^{15}_{8}O \longrightarrow {}^{15}_{7}N + {}^{0}_{+1}e$
* $^{1}_{1}H + {}^{15}_{7}N \longrightarrow {}^{12}_{6}C + {}^{4}_{2}He + \gamma$

26 **The opposite table represents three different isotopes of carbon elements :**

$^{9}_{6}C$	$^{12}_{6}C$	$^{17}_{6}C$

(1) Which isotope(s) emit(s), (with explanation) :

1- Radiation affects sensitive films ?

2- Positron ?

3- Beta particles ?

(2) Is the product of complete combustion of carbon-12 different from that of carbon-17 ? Explain.

27 **Fig. (X) is observed as a sticker on some agricultural products such as strawberry to indicate that it was exposed to gamma radiation, while fig. (Y) is observed as a sticker on uranium preserving containers..**

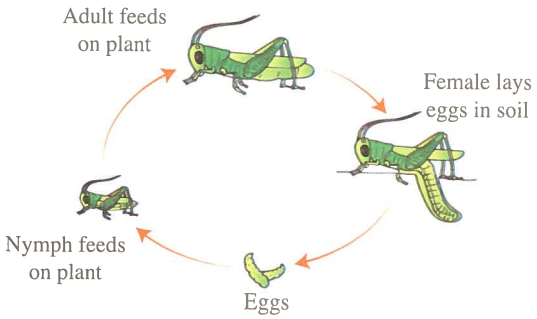
(X)

(Y)

(1) Why are the agricultural products labeled by the sign (X) exposed to gamma radiation ?

(2) What is the indication of the sign (Y) observed on some containers ?

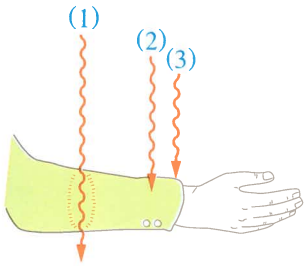
28 **The opposite figure represents the life cycle of one of the agricultural pests :**



(1) How can the females and the nymphs be exterminated by one of the products of chemical reactions ?

(2) How can the spreading of agricultural pests be limited by one of the products of the nuclear reactions ?

29 **Replace the numbers shown on the opposite figure with what is suitable from the following :**



- Gamma rays.
- X-ray.
- Alpha radiation.
- Neutron.
- Beta radiation.

New types of questions ?

Answered

Choosing two out of five choices questions :

1 What are the two isotopes that can be used in the nuclear fusion reactions ? .....

(a) $^{235}_{92}U$ (b) $^{3}_{2}He$ (c) $^{1}_{1}H$

(d) $^{4}_{2}He$ (e) $^{238}_{92}U$

2 What are the two conditions that must be met in the radioactive isotopes which are used for medical purposes ? .....

(a) To have short half life time. (b) To come out of the body slowly.

(c) To have long half life time. (d) To come out of the body rapidly.

(e) To affect all body cells.

3 In the following balanced nuclear equation :

$$^{12}_{6}C + ^{249}_{98}Cf \longrightarrow ^{257}_{104}Rf + nX$$

What are the two choices which fulfill the balancing of this equation ? .....

(a) n = 3 (b) X = $^{0}_{-1}e$ (c) n = 4

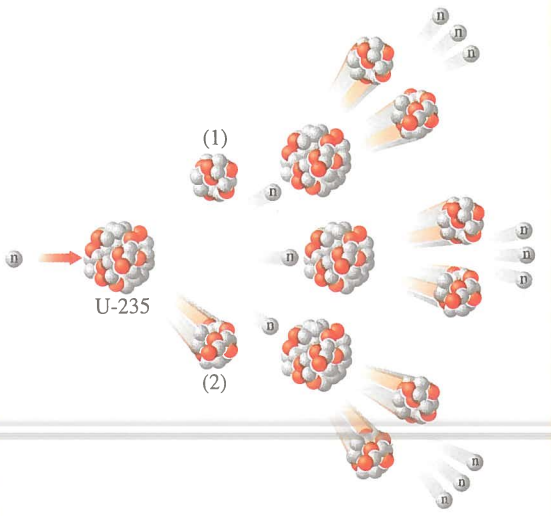
(d) X = $^{1}_{0}n$ (e) X = $^{4}_{2}He$

The sketch questions :

4 The opposite figure shows a chain reaction..

Choose from the following list what is suitable for each of (1) and (2) :

Krypton –90	Krypton –92	Krypton –94
Barium –139	Barium –140	Barium –141



- (1) represents .....
- (2) represents .....

General Exercises ON UNIT 5

Answered

Multiple choice questions

1 According to the relation between mass and energy as defined by Einstein..
What is the value of the mass which can be converted to 1.55×10^{-10} J ? .....

(a) 1.7×10^{-27} kg (b) 0.5×10^{-26} kg (c) 2×10^{-26} kg (d) 3×10^{-27} kg

2 What are the constituents of the protons in the nucleus of lithium $^{7}_{3}Li$? .....

Choices	(a)	(b)	(c)	(d)
Up quarks	4	10	3	6
Down quarks	8	11	6	3

3 The nucleus of tritium $^{3}_{1}H$ contains the quarks .....

(a) 4u + 4d (b) 5u + 5d (c) 4u + 5d (d) 5u + 4d

4 Thorium $^{226}_{90}Th$ can be transformed to $^{214}_{84}Po$ spontaneously.. What is the number of α-particles which accompany this transformation ? .....

(a) 1 (b) 2 (c) 3 (d) 4

5 When the nucleus of $^{273}_{93}X$ emits one α-particle, then two β^--particles, so it is transformed into the nucleus of .....

(a) $^{268}_{92}Y$ (b) $^{270}_{93}X$ (c) $^{270}_{90}Y$ (d) $^{269}_{93}X$

6 According to the equation : $^{234}_{90}X \longrightarrow Y + \beta^-$
Which of the following choices represents the element Y and the type of the nuclear transmutation ? .....

Choices	(a)	(b)	(c)	(d)
Element Y	$^{234}_{89}Y$	$^{234}_{90}Y$	$^{234}_{91}Y$	$^{234}_{91}Y$
Type of transmutation	Natural	Artificial	Natural	Artificial

7 What is the quantity of energy produced from the conversion of 80% of 10 g of a certain substance ? .....

(a) 9.48×10^{-24} MeV (b) 9.48×10^{-27} MeV
(c) 4.48×10^{24} MeV (d) 4.49×10^{27} MeV

8 Which of the following processes represents a nuclear fission reaction ? .....

(a) Disintegration of the nucleus of polonium $^{215}_{84}Po$ to the nucleus of bismuth $^{214}_{83}Bi$

(b) Bombarding neptunium $^{239}_{93}Np$ nucleus with a neutron $^{1}_{0}n$

(c) Combination of lithium $^{6}_{3}Li$ nucleus with a neutron $^{1}_{0}n$

(d) Reaction of the two nuclei of deuteron to form $^{3}_{2}He$

9 The two following equations represents two nuclear reactions :

(1) $^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n + Energy$

(2) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{138}_{55}Cs + {}^{96}_{37}Rb + 2{}^{1}_{0}n + Energy$

Which of the following statements is correct ? .....

(a) Reaction (2) is fission and produces energy higher than that produced from reaction (1).

(b) Reaction (1) is fission and produces energy lower than that produced from reaction (2).

(c) Reaction (2) is fusion and produces energy lower than that produced from reaction (1).

(d) Reaction (1) is fusion and produces energy higher than that produced from reaction (2).

10 In the following two reactions :

(1) $^{243}_{96}Cm \longrightarrow 2{}^{4}_{2}He + X$

(2) $X + {}^{1}_{0}n \longrightarrow {}^{90}_{37}Rb + {}^{144}_{55}Cs + 2{}^{1}_{0}n + E$

What are the types of the two reactions ? .....

Choices	(a)	(b)	(c)	(d)
Reaction (1)	Nuclear fusion	Nuclear fission	Natural transmutation	Elemental transmutation
Reaction (2)	Nuclear fission	Nuclear fusion	Nuclear fission	Natural transmutation

11 If the reaction (X) can not be achieved in the nuclear reactors unlike the reaction (Y), Which of the following choices represents the reactions (X) and (Y) ? .....

Choices	(a)	(b)	(c)	(d)
Reaction (X)	Nuclear fusion	Nuclear fission	Nuclear fission	Nuclear fusion
Reaction (Y)	Nuclear fusion	Nuclear fusion	Nuclear fission	Nuclear fission

Miscellaneous questions

12 Assisted by the information in the opposite table about the two isotopes of the element (X)..

Calculate its atomic mass.

Isotope	^{4}X	^{5}X
Contribution of isotope in atomic mass	4.035	4.088
Isotope percentage in the sample	88%	

13 Element X has two isotopes which are ^{12}X and ^{14}X, the atomic mass of this element is 12.3 u and the contribution of the isotope ^{14}X in the atomic mass = 1.05 u,
Calculate the contribution of the isotope ^{12}X in the atomic mass.

14 **Calculate the actual mass of the nucleus of nitrogen $^{14}_{7}N$, knowing that :**
- Nuclear binding energy per nucleon = 6.974 MeV
- Proton mass = 1.00728 u
- Neutron mass = 1.0087 u

15 **Calculate the actual mass** of the nucleus of an element whose atomic number is 3 and the mass of its neutrons = 3.02598 u, knowing that the nuclear binding energy per nucleon = 5.1205 MeV, proton mass = 1.00728 u, and neutron mass = 1.00866 u

16 An element with mass number 14, its nuclear binding energy per nucleon = 34.1411 MeV, and its actual mass is 13.6 u
Calculate the atomic number of this element, knowing that :
- Proton mass = 1.0073 u
- Neutron mass = 1.0087 u

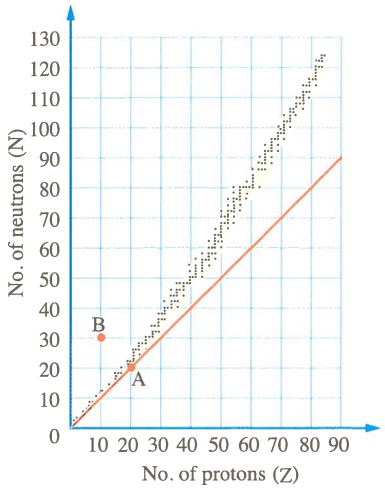
17 **Here are four letters referring to four different elements :**

$$(^{56}_{26}A\ ,\ ^{206}_{82}B\ ,\ ^{244}_{94}C\ ,\ ^{39}_{19}D)$$

Which of these elements is radioactive ? Give reason.

18 An element $^{227}_{80}X$, **Determine its location** relating to the belt of stability, **then illustrate how** this element can reach the stability state.

19 **According to the opposite figure :**
Why is element (A) stable unlike element (B) ?



20 A radioactive element, its mass = 24 g and its half-life is 14 years, 93.75% of it decayed..
Calculate the time consumed in this decaying.

21 A radioactive element has half-life 0.5 day, 0.25 g of its original mass remain after 3 days..
Calculate its original mass.

Exam model about Unit 5

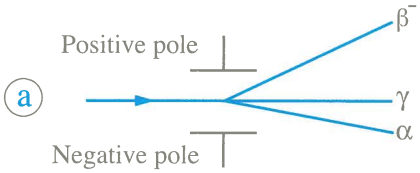
Answered

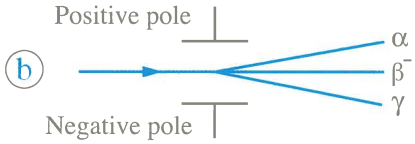
Rate your level

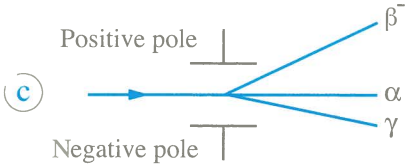
Superior	Remarkable	above average	Weak
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	less than 10 marks

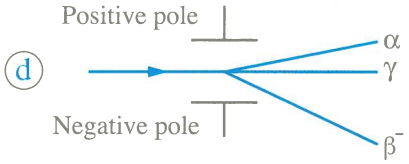
Choose the correct answer for the questions 1 : 10 ..... 10 marks

1 A beam of particles is emitted from a radioactive element to pass through the two poles of an electric field.. Which of the following choices represents the correct path of each of these particles ? .....

(a)


(b)


(c)


(d)


2 All the following particles are charged except .....

(a) alpha particle. (b) beta particle. (c) neutron. (d) proton.

3 The following elements have radioactive isotopes.. Which of them is a source of energy because of its radioactivity ? .....

(a) Carbon. (b) Hydrogen. (c) Iodine. (d) Uranium.

4 The ratio of number of d quarks : number of u quarks in the proton is .....

(a) 3d : 1u (b) 2d : 1u (c) 1d : 3u (d) 1d : 2u

5 Which of the following choices represents correctly gamma ray and beta particle ? .....

Choices	Gamma ray	Beta particle
(a)	Has very high velocity	Electromagnetic radiations
(b)	Electromagnetic radiations	Nucleus of helium atom
(c)	Electromagnetic radiations	Has medium ability of penetration
(d)	Has very high velocity	Is not affected by electrical field

6 Each of the following is a nuclear fusion reaction, except .....

(a) ${}_1^2H + {}_1^3H \longrightarrow {}_2^4He + {}_0^1n$

(b) ${}_1^2H + {}_1^2H \longrightarrow {}_2^3He + {}_0^1n$

(c) ${}_1^2H + {}_1^2H \longrightarrow {}_2^4He$

(d) ${}_7^{14}N + {}_0^1n \longrightarrow {}_6^{14}C + {}_1^1H$

7 Among the methods of killing the cancer cells, is by implanting needles in them contain .....

(a) radium-226 which emits alpha particles.
(b) cobalt-60 which emits gamma rays.
(c) cesium-137 which emits gamma rays.
(d) strontium-90 which emits beta particles.

8 The idea of the fission bomb depends on .....

(a) using an amount of uranium-238 exceeds the definite volume.
(b) occurrance of a serial reaction for uranium-235
(c) placing cadmium rods in between uranium-235 rods.
(d) occurrance of a nuclear fission reaction with fast rate leading to exploding all uranium-238 nuclei.

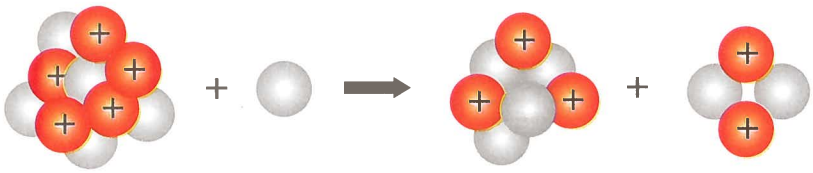
9 The nucleus of magnesium atom is symbolized by $^{24}_{12}Mg$,
What is the ratio of the numbers of quarks $\frac{d}{u}$ in magnesium nucleus ? .....

(a) 2 : 3 (b) 3 : 2 (c) 2 : 1 (d) 1 : 1

10 If you know that the mass of neutron = 1.00866 u, that of proton = 1.00728 u, and the nuclear binding energy per nucleon in the nucleus of $^{28}_{14}Si$ = 8.21275 MeV..
What is the value of the actual mass of the nucleus of silicon-28 ? .....

(a) 28.22316 u (b) 27.97616 u
(c) 229.957 u (d) 279.7616 u

11 The following figure represents a nuclear transmutation :



(1) Write the balanced nuclear equation which represents this reaction.

.....

.....

(2) Is the daughter nucleus stable or unstable ? Explain.

.....

.....

..... 2 marks

12 In terms of the data in the opposite table :

Calculate the atomic mass of magnesium Mg

Isotope	Abundance in nature	Relative atomic mass
$^{24}_{12}Mg$	78.99%	23.985 u
$^{25}_{12}Mg$	10%	24.986 u
$^{26}_{12}Mg$	11.01%	25.983 u

..... 1 mark

13 **Calculate the original mass** of a radioactive element which after passing 2.5 days, 0.0625 g of it remained, knowing that its half-life is 0.5 day.

..... 1 mark

14 In the nuclear reaction : $^{60}_{27}Co \longrightarrow {}^{60}_{28}Ni + {}^{0}_{-1}e$

If the difference between the masses of the products and those of the reactants = 0.003 g

Calculate the amount of the produced energy (in J).

..... 1 mark

15 **Determine the locations of the following unstable nuclei related to the belt of stability, with giving reason..**

Then determine the radiation which is emitted from each of them to reach the stability state :

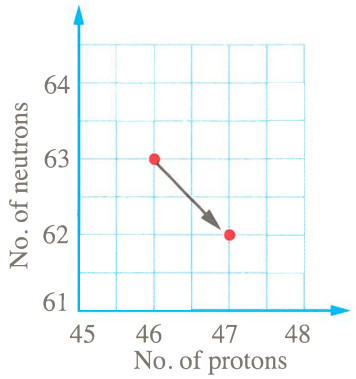
(1) Neon-24

(2) Chlorine-32

..... 2 marks

16 **Write the balanced nuclear equation which represents the process illustrated in the opposite graph.. knowing that :**

- Atomic number of Pd isotope = 46
- Atomic number of Ag isotope = 47



.....

.....

.....

.....

..... 1 mark

17 **Use the following elements and isotopes to write two different equations which represent correctly two nuclear reactions..**

«Some of them can be used more than once».

$^{1}_{0}n$	$^{17}_{8}O$	$^{14}_{7}N$	$^{4}_{2}He$	$^{3}_{2}He$	$^{2}_{1}H$	$^{1}_{1}H$

.....

.....

.....

.....

..... 2 marks

GO

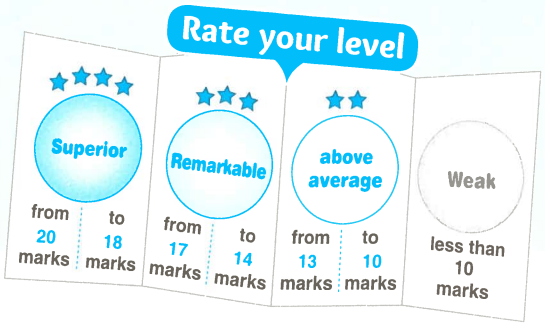
Open Book Examination Models

Answered

About the curriculum of the Second Term

Exam model 1

Answered



Choose the correct answer for the questions 1 : 10 . ..... 10 marks

1 Which of the following remains constant in the closed system ? .....

(a) Energy. (b) Mass. (c) Temperature. (d) Enthalpy.

2 What is the change in enthalpy on dissolving 40 g of NaOH in water to form one liter of solution, knowing that the temperature rised by 10.6°C ? ..... [NaOH = 40 g/mol]

(a) – 0.443 kJ/mol (b) – 4.4308 kJ/mol (c) – 44.308 kJ/mol (d) – 443 kJ/mol

3 From the two following equations :

$I_{2(s)} \longrightarrow I_{2(\ell)}$ $\Delta H = +16$ kJ/mol

$I_{2(s)} \longrightarrow I_{2(v)}$ $\Delta H = +62$ kJ/mol

What is the change in the molar enthalpy of iodine vaporization according to the equation : $I_{2(\ell)} \longrightarrow I_{2(v)}$? .....

(a) –78 kJ/mol (b) – 46 kJ/mol (c) + 46 kJ/mol (d) +78 kJ/mol

4 In the reaction : $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)} + 112$ kJ

Which of the following choices represents both the sign of ΔH of the reaction, and the type of the reaction ? .....

Choices	(a)	(b)	(c)	(d)
Sign of ΔH	Negative	Positive	Negative	Positive
Type of the reaction	Endothermic	Endothermic	Exothermic	Exothermic

5 Anhydrous copper (II) chloride combines with water to form hydrated copper (II) chloride, according to the equation : $CuCl_2 + 2H_2O \longrightarrow CuCl_2.2H_2O$, by knowing the ΔH_f° values of the substances shown in the opposite table..

Substances	ΔH_f° (kJ/mol)
H_2O	–286
$CuCl_2$	–206
$CuCl_2.2H_2O$	–808

What is the change in heat content of this process ? .....

(a) –1586 kJ/mol (b) –316 kJ/mol (c) –110 kJ/mol (d) –30 kJ/mol

6 Which of the following choices represents both the relative mass of neutron and the path of a beam of it through an electric field ? .....

Choices	(a)	(b)	(c)	(d)
Relative mass	0	1	0	1
Path of beam	Deviates	Deviates	Doesn't deviate	Doesn't deviate

7 Which of the following choices represents both the heaviest stable nucleus, and the number of the neutrons in it ? .....

Choices	(a)	(b)	(c)	(d)
Heaviest stable nucleus	Carbon $^{12}_{6}C$	Uranium $^{235}_{92}U$	Lead $^{208}_{82}Pb$	Lead $^{208}_{82}Pb$
No. of neutrons in it	6	43	126	208

8 The opposite table shows the masses and the percentages of abundance of two isotopes of lithium in nature.. Which of the following relations represents the method of calculating the atomic mass of lithium ? .....

Isotope	Relative atomic mass	Abundance in nature
^{6}Li	6.02 u	7.5%
^{7}Li	7.02 u	92.5%

(a) [(0.075) (6.02 u) + (0.925) (7.02 u)].

(b) [(7.5) (6.02 u) + (92.5) (7.02 u)].

(c) [(0.925) (6.02 u) + (0.075) (7.02 u)].

(d) [(92.5) (6.02 u) + (7.5) (7.02 u)].

9 In one of the nuclear reactors, a nucleus of uranium-238 is bombarded with deuteron $^{2}_{1}H$, according to the equation : $^{238}_{92}U + ^{2}_{1}H \longrightarrow X + 2^{1}_{0}n$

What is the symbol of the produced isotope (X) ? .....

(a) $^{238}_{93}Np$ (b) $^{238}_{94}Pu$ (c) $^{240}_{93}Np$ (d) $^{240}_{94}Pu$

10 Which of the following choices represents the ratio between the numbers of quarks $\frac{u}{d}$ in helium nucleus ? .....

(a) 2 : 3 (b) 3 : 2 (c) 2 : 1 (d) 1 : 1

11 **Calculate ΔH value of the reaction :** $2CH_3OH_{(\ell)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 4H_2O_{(\ell)}$

Knowing that on the combustion of 0.934 g of methanol CH_3OH

(its molar mass is 32 g/mol), a quantity of heat equals 20.6 kJ is released.

.....

.....

.....

..... 1 mark

12 **Why** doesn't the number of nucleons change on emission of gamma radiations from the nucleus of $^{214}_{84}Po$ atom ?

.....

.....

..... 1 mark

13 When a radioactive element was put in front of Geiger counter, the reading was 4000 decay/min, after passing 72 min, the reading became 500 decay/min

Calculate the half-life of this element.

.....

.....

.....

..... 1 mark

14 **Calculate the heat quantity - in kJ -** required to raise the temperature of 48.7 g of water from 22.8°C to 62°C

.....

.....

.....

..... 1 mark

15 The average bond energy (S=O) in SO_3 compound differs from that in SO_2 compound..

Explain by applying chemical calculations to the following reaction :

$$2O=S=O_{(g)} + O=O_{(g)} \longrightarrow 2O=\overset{O}{\overset{\|}{S}}=O_{(g)} \quad \Delta H = -196 \text{ kJ}$$

The bond	Average bond energy (kJ/mol)
S=O in SO_2	534
O=O	498

.....

.....

.....

.....

.....

.....

.....

.....

.....

2 marks

Study the following diagram, then answer the questions 16 , 17 :

In the following scheme :

$^{214}_{83}Bi$ —(1)→ $^{214}_{84}Po$ —beta→ A —alpha→ $^{210}_{83}Bi$ —beta→ B —(2)→ $^{206}_{82}Pb$ (Stable isotope)

16 **Write** the mass number and the atomic number of each of the elements (A) and (B).

.....

.....

17 **Define** the type of the emitted particle in each of (1) and (2).

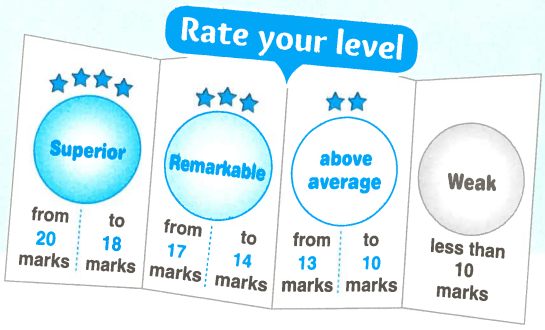
.....

.....

4 marks

Exam model 2

Answered



Choose the correct answer for the questions 1 : 10

..... 10 marks

1 It is known that gases are bad electrical conductors.. Which of the following has higher ability to make gases conduct electricity ? .....

(a) Alpha particles. (b) Beta particles. (c) Gamma rays. (d) Neutrons.

2 A sample of wood contains 9×10^6 nuclei of carbon-14 atoms, whose half-life is 5600 years.. What is the number of nuclei of carbon-14 which remains in the wood sample after passing 16800 years ? .....

(a) 1.125×10^2 nuclei. (b) 1.125×10^6 nuclei.

(c) 2.25×10^{16} nuclei. (d) 4.5×10^{16} nuclei.

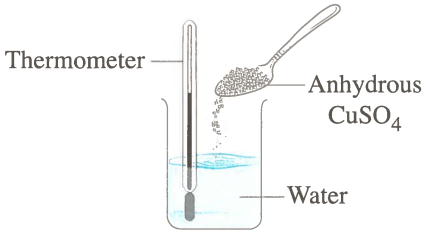
3 In the opposite figure, on dissolving anhydrous copper (II) sulphate in water, the reading of thermometer rises, which means that this process is .....

(a) endothermic and ΔH value has a positive sign.

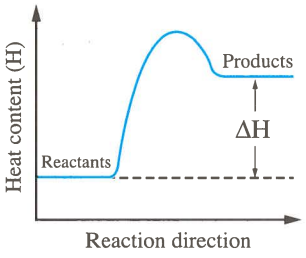
(b) endothermic and ΔH value has a negative sign.

(c) exothermic and ΔH value has a negative sign.

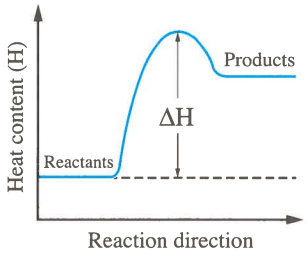
(d) exothermic and ΔH value has a positive sign.



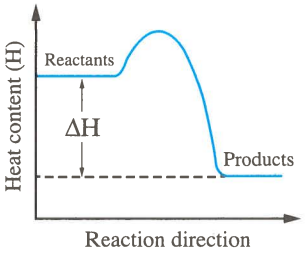
4 Which of the following energy diagrams represents an endothermic reaction ? .....



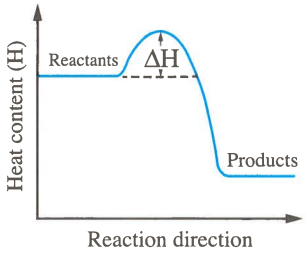
(a)



(b)



(c)



(d)

5 On bombarding a nucleus of boron-11 atom by an alpha particle, a nucleus of a new element is formed with releasing a neutron.. Which of the following equations represents this nuclear reaction ? .....

(a) $^{11}_{5}B + ^{1}_{1}H \longrightarrow ^{11}_{6}C + ^{1}_{0}n$

(b) $^{11}_{5}B + ^{2}_{2}He \longrightarrow ^{12}_{7}N + ^{1}_{0}n$

(c) $^{11}_{5}B + ^{4}_{2}He \longrightarrow ^{14}_{6}C + ^{1}_{1}n$

(d) $^{11}_{5}B + ^{4}_{2}He \longrightarrow ^{14}_{7}N + ^{1}_{0}n$

6 Many nuclear reactions take place in the nuclear reactors, among them is the reaction represented by the equation : $^{113}_{48}Cd + ^{1}_{0}n \longrightarrow ^{114}_{48}Cd + X$

What does the letter X represent ? .....

(a) α (b) β^+ (c) β^- (d) γ

7 The following equation represents the reaction of adding hydrogen to ethylene gas :

$$H_2C{=}CH_{2(g)} + H_{2(g)} \longrightarrow C_2H_{6(g)}$$

What is the value of ΔH of this reaction ? .....

(a) –560 kJ/mol (b) –124 kJ/mol

(c) +486 kJ/mol (d) +5496 kJ/mol

The Bond	The average bond energy (kJ/mol)
C – C	350
C = C	610
C – H	410
H – H	436

8 Nitrogen dioxide decomposes according to the following thermochemical equation : $2NO_{2(g)} \longrightarrow N_{2(g)} + 2O_{2(g)}$ $\Delta H = -66$ kJ

What is the change in enthalpy of the reaction :

$\frac{1}{2}N_{2(g)} + O_{2(g)} \longrightarrow NO_{2(g)}$? .....

(a) –66 kJ/mol (b) –33 kJ/mol (c) +33 kJ/mol (d) +66 kJ/mol

9 The nucleus of one of lead isotopes contains 82 protons.. What is its probable symbol ? .....

(a) $^{207}_{82}PB$ (b) $^{82}_{206}PB$ (c) $^{210}_{128}Pb$ (d) $^{208}_{82}Pb$

10 The hotness of desert at the day and its coldness at night indicate that it is .....

(a) a closed system.

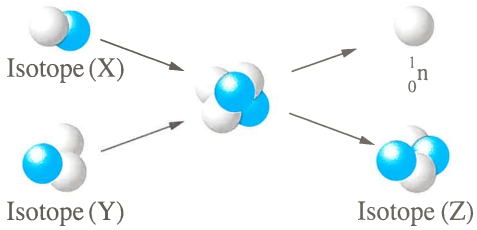
(b) an open system.

(c) an isolated system.

(d) an equilibrium system.

11 **The opposite reaction represents a nuclear fusion reaction..**

Write the nuclear equation which represents this reaction, with stating what are referred to by (X), (Y) and (Z).



.....

.....

..... 1 mark

12 From the following two thermochemical equations :

① $\frac{1}{2}N_{2(g)} + O_{2(g)} \longrightarrow NO_{2(g)}$, $\Delta H_1 = +30$ kJ/mol

② $N_{2(g)} + 2O_{2(g)} \longrightarrow N_2O_{4(g)}$, $\Delta H_2 = +10$ kJ/mol

Calculate the change in enthalpy for the opposite reaction : $N_2O_{4(g)} \longrightarrow 2NO_{2(g)}$

.....

.....

.....

..... 1 mark

13 Cancer cells can be killed by being exposed to gamma radiation emitted from cobalt-60 isotope to the center of the tumor or by implanting a needle of radium-226 isotope - which emits alpha particles - inside the tumor.

Why is cobalt-60 isotope used outside the body, while radium-226 isotope used in the tumor inside the body ?

.....

.....

..... 1 mark

14 Two pieces have equal masses and same temperature are heated for an equal period of time by one thermal source :

- The first piece is of copper (its specific heat is 0.385 J/g.°C).
- The second piece is of iron (its specific heat is 0.444 J/g.°C).

Which one of them its temperature rises more ? Why ?

.....

.....

..... 1 mark

15 **Calculate the change in heat content ΔH_c° for the following reaction :**

$$CH_3OH_{(\ell)} + O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(\ell)}$$

Knowing that enthalpies of formation ΔH_f° of the substances are as the following :

$H_2O_{(\ell)} = -285.5$ kJ/mol , $CO_{2(g)} = -393.51$ kJ/mol , $CH_3OH_{(\ell)} = -238$ kJ/mol

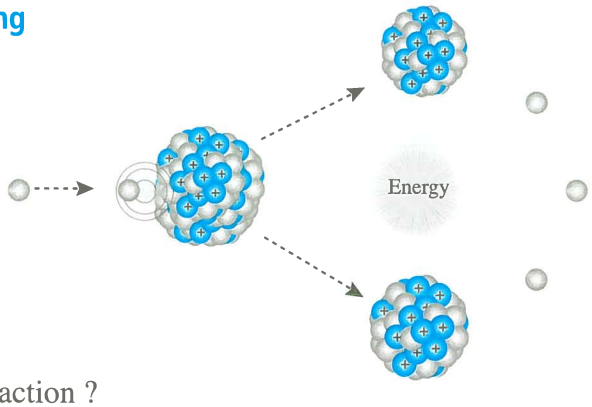
.....

.....

.....

..... / 2 marks

16 **The opposite figure represents bombarding the nucleus of an element with a particle to form different products :**



(1) **What** is the name of the process represented in this figure ?

.....

.....

(2) **Why** does this process lead to a serial reaction ?

.....

.....

..... / 2 marks

17 The quantity of heat produced from the combustion of 1.3 g of glucose (its molar mass is 180 g/mol) raises the temperature of an unknown mass of pure water by 24.3°C, knowing that the standard heat of combustion of glucose equals –2816 kJ/mol

Calculate the mass of water used.

.....

.....

.....

.....

.....

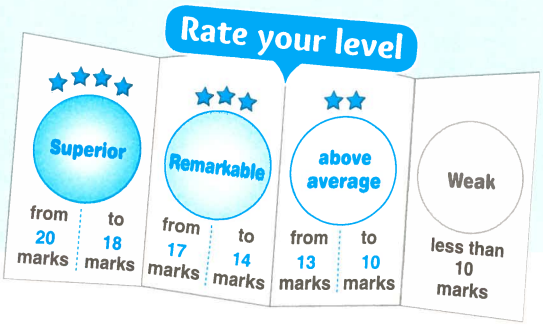
.....

.....

..... / 2 marks

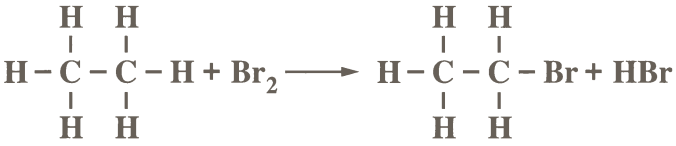
Exam model 3

Answered



Choose the correct answer for the questions 1 : 10 ..... 10 marks

1 The following reaction involves breaking and formation of bonds :



Bond	Average bond energy (kJ/mol)
Br – Br	194
H – Br	362
C – H	414
C – Br	285

What is the change in heat content of this reaction ? .....

(a) –39 kJ/mol (b) –1255 kJ/mol (c) +1255 kJ/mol (d) +39 kJ/mol

2 Which one of the following shows both the charge and the location of electrons inside the atom ? .....

Choices	(a)	(b)	(c)	(d)
The charge	Negative	Negative	Positive	Positive
Located inside the nucleus	No	Yes	No	Yes

3 From the following two thermal equations :

* $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\Delta H = -393.5$ kJ/mol
* $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(\ell)}$ $\Delta H = -571.6$ kJ

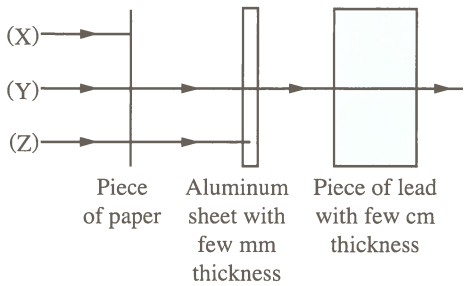
What is the enthalpy change of the following reaction ? .....

$C_{(s)} + 2H_2O_{(\ell)} \longrightarrow CO_{2(g)} + 2H_{2(g)}$

(a) – 965.1 kJ (b) –107.7 kJ (c) +178.1 kJ (d) +679.3 kJ

4 A radioactive source emits three types of radiations, they are represented by (X), (Y) and (Z).. What is the type of these radiations ? .....

Choices	(X)	(Y)	(Z)
(a)	Alpha	Beta	Gamma
(b)	Alpha	Gamma	Beta
(c)	Beta	Alpha	Gamma
(d)	Gamma	Beta	Alpha



5 **On adding 50 g of water whose temperature is 90°C to a calorimeter containing 50 g of water whose temperature is 15°C, the thermometer reading rises up to 45°C ,so the heat absorbed by the calorimeter equals** .....

(a) the heat lost by the hot water.

(b) the heat gained by the cold water.

(c) the sum of the heat lost by the hot water and the heat gained by the cold water.

(d) the difference between the heat lost by the hot water and the heat gained by the cold water.

6 **The radioactive isotope of iodine-131 whose half-life is 8 days emits β^--particles transforming into xenon-131 isotope..**

Which of the following statements represents this natural transmutation ? .....

(a) The emission of β^--particles stops after 8 days.

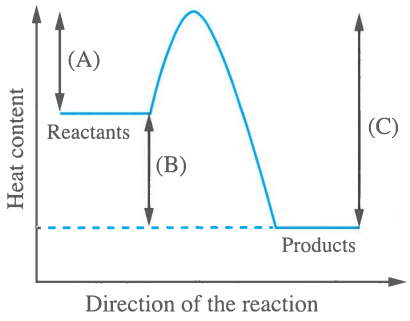
(b) The life time of xenon-131 atoms reaches its half after 8 days.

(c) All the iodine-131 nuclei decay after 16 days.

(d) The number of iodine-131 nuclei is reduced to quarter after 16 days.

7 **In terms of the opposite energy diagram..**

Which of the following statements is correct ? .....



(a) (A) represents the released heat during the formation of bonds.

(b) (C) represents the absorbed heat during the breaking of bonds.

(c) (B) represents the released heat from the reaction.

(d) The difference between (B) and (C) represents the released heat from the reaction.

8 **An element has an atomic number 3, the nucleus of its atom contains 10 upper quarks and 11 down quarks. So, its mass number is** .....

(a) 6 (b) 7 (c) 13 (d) 21

9 **When a nucleus of a radioactive element whose number of nucleons equals 128 loses a β^--particle, it is transformed into a new element whose number of nucleons equals** .....

(a) 124 (b) 127

(c) 128 (d) 129

10 **The following nuclear reaction represents what happens to the boron rods which are used in some nuclear reactors :** $^{10}_{5}B + {}^{1}_{0}n \longrightarrow {}^{7}_{3}Li + {}^{4}_{2}He$

What is the probable role of the boron rods in the nuclear fission reactor ? .....

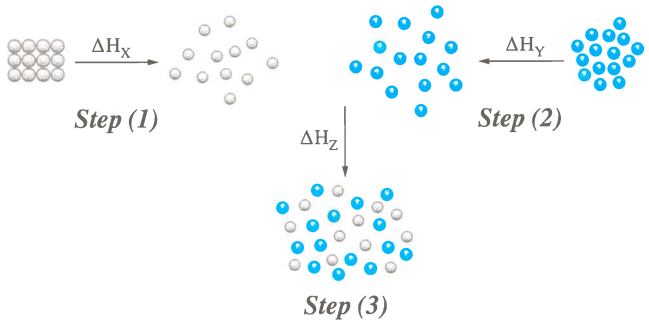
(a) Decreasing the neutrons speed to increase the rate of fission reactions.

(b) Decreasing the neutrons energy without absorption.

(c) Absorbing neutrons to decrease the rate of fission reactions.

(d) Increasing the ability of neutrons to make fission reactions.

Study the following figure, then answer the questions 11 , 12 :



11 **What** does step (1) represent ?

.....

12 **What** do you conclude when : $(\Delta H_X + \Delta H_Y) > \Delta H_Z$?

.....

..... / 2 marks

13 **Calculate the total heat released** from the combustion of a mixture formed from 100 g of butane C_4H_{10} (its heat of combustion = – 49.7 kJ/g) with 200 g of liquid octane C_8H_{18} (its heat of combustion = – 47.9 kJ/g).

.....

.....

.....

.....

.....

.....

.....

.....

..... / 2 marks

Study the following paragraph, then answer the questions 14 , 15 :

"The emission of β^--particle from the nucleus of element (X) transforms it into the nucleus of nitrogen atom $^{14}_{7}N$" :

14 **What** is the location of element (X) related to the belt of stability ?

.....

15 **Mention** one similarity and one difference between β^+ and β^-

.....

.....

..... 2 marks

16 **The figure (X) is being seen on some agricultural products as strawberry, to indicate its exposure to γ-rays, while the figure (Y) is seen as a sticker on uranium preserving containers :**

(X)

(Y)

(1) **Why** are some agricultural products labeled by the symbol (X) exposed to γ-radiations ?

.....

(2) **What** is the indication of the sign (Y) which is observed on some containers ?

.....

..... 2 marks

17 **During the fusion of deuterium nucleus with tritium nucleus, a nucleus of helium atom $^{4}_{2}He$ and another particle are formed.**

(1) **Write the nuclear equation** that expresses the occurring nuclear fusion.

.....

(2) **Calculate the value of the energy resulted from the nuclear fusion in :**

1. MeV **2.** Joule (J).

"Knowing that the fused nuclei mass equals 5.031 u and the mass of the resulted nucleus equals 5.011 u".

.....

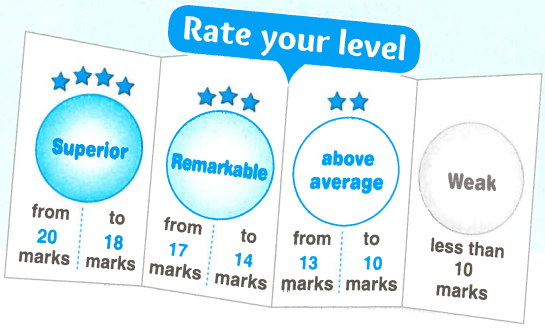
.....

.....

..... 2 marks

Exam model 4

Answered



Choose the correct answer for the questions 1 : 10

..... / 10 marks

1 The quantity of heat of 2 cal is equivalent to .....

(a) 0.47 kJ
(b) 8.36 kJ
(c) 8.36×10^{-3} kJ
(d) 8.36×10^{3} kJ

2 All the following are from the properties of strong nuclear force, except that .....

(a) it's found between a proton and an electron.
(b) it is a great force.
(c) it is a short-range force.
(d) it doesn't depend on the charge of nucleons.

3 Plant cells use the light energy in photosynthesis process..
Which of the following statements represents correctly that process ? .....

(a) It is an endothermic process / As the heat released during the formation of the bonds in products molecules is less than the heat required for breaking the bonds in reactants molecules.
(b) It is an endothermic process / As the heat released during the formation of the bonds in products molecules is more than the heat required for breaking the bonds in reactants molecules.
(c) It is an exothermic process / As the heat released during the formation of the bonds in products molecules is less than the heat required for breaking the bonds in reactants molecules.
(d) It is an exothermic process / As the heat released during the formation of the bonds in products molecules is more than the heat required for breaking the bonds in reactants molecules.

4 Among the nuclei which lie at the right side of the belt of stability is .....

(a) $^{35}_{19}K$
(b) $^{39}_{19}K$
(c) $^{40}_{20}Ca$
(d) $^{40}_{19}K$

5 Carbon monoxide gas reacts with methanol to form acetic acid CH_3COOH, according to the following equation :

$CO_{(g)} + CH_3OH_{(\ell)} \longrightarrow CH_3COOH_{(\ell)}$

Knowing the standard heat of formation ΔH_f° of the substances shown in the opposite table..

What is the value of ΔH° of this reaction ? .....

Substances	ΔH_f° (kJ/mol)
$CO_{(g)}$	–283
$CH_3OH_{(\ell)}$	–726
$CH_3COOH_{(\ell)}$	–874.1

(a) –1883.1 kJ/mol (b) –134.9 kJ/mol
(c) +134.9 kJ/mol (d) +1883.1 kJ/mol

6 The atomic number of iron is 26, it has four isotopes, which are (^{54}Fe , ^{56}Fe , ^{57}Fe , ^{58}Fe).. Which of the following statements explains the reason that those isotopes have the same chemical properties ? Because they have the same .....

(a) mass number.
(b) number of electrons in the outer energy level.
(c) number of neutrons.
(d) number of protons.

7 What is the number of nucleons in uranium isotope $^{235}_{92}U$? .....

(a) 327 nucleons. (b) 235 nucleons. (c) 143 nucleons. (d) 92 nucleons.

8 The following thermal equation represents the combustion reaction of hexane C_6H_{14} :

$C_6H_{14(g)} + \frac{19}{2} O_{2(g)} \longrightarrow 6CO_{2(g)} + 7H_2O_{(\ell)}$ $\Delta H = -4158$ kJ/mol

What is the value of ΔH of the following hypothetical reaction,

$12CO_{2(g)} + 14H_2O_{(\ell)} \longrightarrow 2C_6H_{14(g)} + 19O_{2(g)}$? .....

(a) + 8316 kJ (b) + 4158 kJ (c) – 2079 kJ (d) – 3568 kJ

9 The ratio of the number of up quarks in the neutron to the number of down quarks is .....

(a) the quarter. (b) the double. (c) the half. (d) four times.

10 A container filled with water may represent .....

(a) a closed system. (b) an open system.
(c) an isolated system. (d) an equilibrium system.

11 What is the symbol of the isotope (Y) that results from the radioactivity of the element (X), according to the equation : $^{A}_{Z}X \longrightarrow {}^{.....}_{.....}Y + {}^{4}_{2}He$

.....

..... / 1 mark

12 **What is the scientific explanation for that the ΔH° value of the following equation has a positive sign ?** $H_2O_{(s)} \longrightarrow H_2O_{(\ell)}$ $\Delta H° = +6.03$ kJ/mol

.....

.....

.....

..... / 1 mark

13 **Calculate** the value of the specific heat of water in J/kg.°C unit.

.....

.....

..... / 1 mark

14 Two elements (X) and (Y) have the same number of nucleons, if the ratio $\left(\frac{N}{Z}\right)$ for element (X) equals 1 and for element (Y) equals 1.5, **deduce the chemical symbol of the stable atom (Y),** knowing that the nucleus of element (X) contains 5 protons.

.....

.....

.....

.....

.....

.....

.....

..... / 1 mark

15 The quantity of energy required to convert 1 mol of liquid water at 100°C to water vapor is 54 kJ/mol, **calculate the total energy** required to convert 100 g of liquid water at 20°C to water vapor at 100°C **[H_2O = 18 g/mol]**

.....

.....

.....

.....

.....

.....

.....

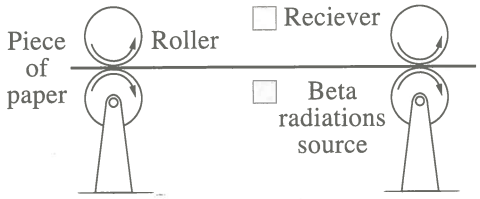
.....

.....

.....

..... / 2 marks

16 **The paper thickness is measured by using a source of beta radiations and a reciever for those radiations..**
as shown in the opposite figure :



(1) **Why** are alpha or gamma radiations not used in the measuring process ?

.....

.....

(2) If the used beta radiations source is strontium-90 isotope,
complete the following equation :

$$^{90}_{38}Sr \longrightarrow \text{.....}^{\text{.....}}_{\text{.....}}Y + \text{.....}^{\text{.....}}_{\text{.....}}e$$

..... 2 marks

17 **The following reaction takes place in one of the nuclear forces stations :**

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3^{1}_{0}n$$

Calculate the quantity of heat released by knowing the following masses :

- $^{235}_{92}U = 234.9933$ u
- $^{92}_{36}Kr = 91.9064$ u
- $^{141}_{56}Ba = 140.8836$ u
- $^{1}_{0}n = 1.0087$ u

.....

.....

.....

.....

.....

.....

.....

.....

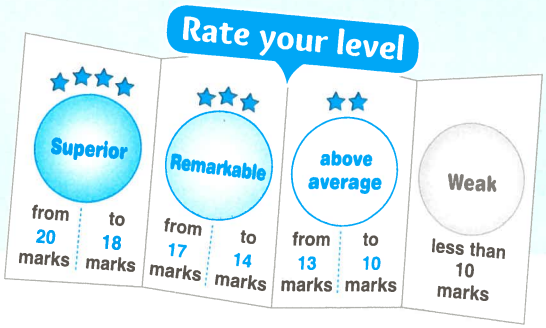
.....

.....

..... 2 marks

Exam model 5

Answered



Choose the correct answer for the questions 1 : 10

10 marks

1 The egg is an example for a(an) .....

(a) closed system
(b) open system
(c) isolated system
(d) closed or open system

2 Why is water used as a cooling substance for car engines ? Because .....

(a) of its low density.
(b) of its high specific heat.
(c) it is cheap.
(d) it is easy to volatilize.

3 Which one of the following elements' atoms pairs contains the same number of neutrons in their nuclei ? .....

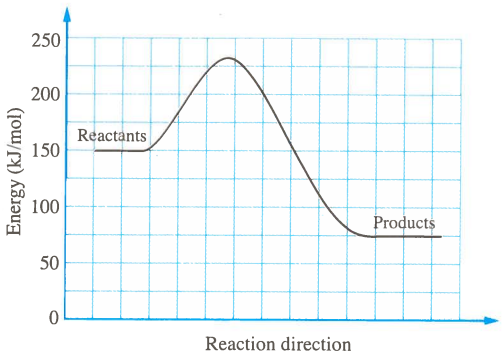
(a) $^{12}_{5}B$, $^{12}_{6}C$
(b) $^{1}_{1}H$, $^{2}_{1}H$
(c) $^{12}_{6}C$, $^{13}_{7}N$
(d) $^{14}_{6}C$, $^{14}_{7}N$

4 Which of the following choices represents the number of quarks in the nucleus of deuterium isotope ? .....

Choices	(a)	(b)	(c)	(d)
Number of up quarks	3	3	6	6
Number of down quarks	3	6	3	6

5 From the opposite energy diagram.. What is the value of the change in heat content of this reaction ? .....

(a) –170 kJ/mol
(b) –75 kJ/mol
(c) +70 kJ/mol
(d) +240 kJ/mol



6 From the following two reactions :

- $S_{(s)} + 1\frac{1}{2} O_{2(g)} \longrightarrow SO_{3(g)}$ $\Delta H° = -395$ kJ/mol
- $SO_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow SO_{3(g)}$ $\Delta H° = -98$ kJ/mol

What is the value of $\Delta H°$ of the reaction : $S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$? .....

(a) –297 kJ/mol (b) +297 kJ/mol (c) –493 kJ/mol (d) +493 kJ/mol

7 Which of the following its number of nucleons equals 4 ? .....

(a) Alpha particle. (b) Beta particle. (c) Gamma radiation. (d) Positron.

8 N , M and L are three elements of mass numbers 235 , 238 and 239 respectively, if you know that the atom of element L has 92 electrons, the atom of element M has 92 protons and the atom of element N has 145 neutrons..

Which of them are isotopes ? .....

(a) L and M only. (b) L and N only. (c) M and N only. (d) L , M and N

9 Phosphorus pentachloride gas decomposes by heat to phosphorus trichloride gas and chlorine gas.. What is the amount of change in the heat content of this reaction ? .....

(a) –90 kJ/mol (b) +90 kJ/mol

(c) –420 kJ/mol (d) +420 kJ/mol

Bond	Average bond energy
P – Cl	330 kJ/mol
Cl – Cl	240 kJ/mol

10 Nitrogen gas reacts with oxygen gas according to the following thermal equation :

$$N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)} \qquad \Delta H = +66 \text{ kJ}$$

What is the enthalpy change on mixing 2 mol of nitrogen gas with 2 mol of oxygen gas ? .....

(a) +16.5 kJ (b) +33 kJ (c) +66 kJ (d) +132 kJ

11 The nucleus of technetium isotope $^{99}_{43}Tc$ produces β^--particle and a neutron to be transformed into the nucleus of ruthenium Ru isotope..

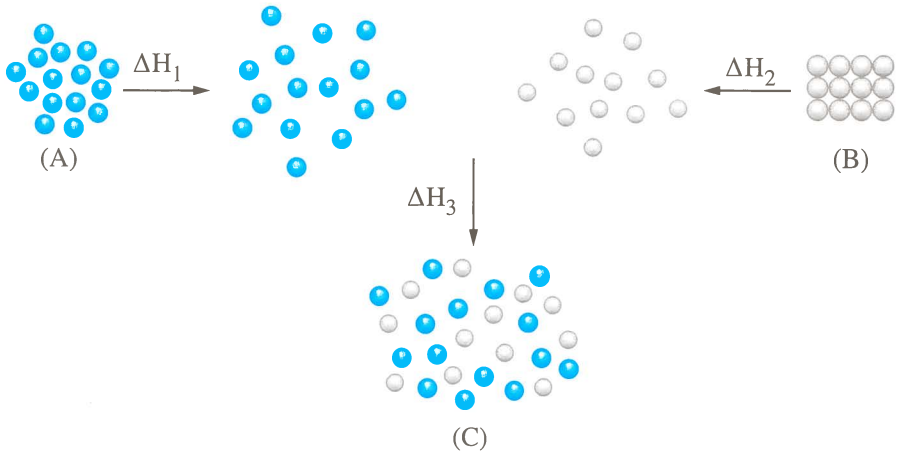
Illustrate this natural transmutation with a balanced nuclear equation.

.....

.....

..... 1 mark

12 **Study the following figure which represents the explanation of the source of the heat of solution of a solid salt dissolved in a liquid solvent, then answer the following :**



(1) What do the letters (A) and (B) represent ?

.....

(2) Does ΔH_3 have negative sign **or** positive sign ? Explain.

.....

..... 1 mark

13 A radioactive element with half-life time 0.5 hour was put in front of Geiger counter, its reading was 6000 decay/second.. **What is the counter reading after 1.5 hour ?**

.....

.....

.....

.....

..... 1 mark

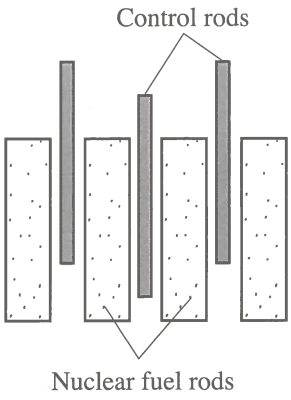
14 **Arrange the following aluminum compounds ascendingly according to their thermal stability :**

Compound	$Al_2(SO_4)_3$	$AlCl_3$	$Al(OH)_3$
Heat of formation (ΔH_f°)	–3440 kJ/mol	–705.63 kJ/mol	–1277 kJ/mol

.....

..... 1 mark

15 **The opposite figure represents a section in the fission nuclear reactor :**



(1) Complete the following equation which illustrates the nuclear fission of the substance of the nuclear fuel :

$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{90}_{.....}Sr + {}^{.....}_{54}Xe + ...$

(2) What does happen to the number of neutrons when the control rods are raised upwards ?

.....

.....

..... 2 marks

16 **Calculate the nuclear binding energy per nucleon** in the nucleus of beryllium atom $^{8}_{4}Be$ in (J), knowing that its actual mass is 1.329×10^{-26} kg and the mass of each proton and neutron is 1.673×10^{-27} kg and 1.675×10^{-27} kg respectively.

.....

.....

.....

.....

.....

.....

.....

..... 2 marks

17 When 50 g sample of copper (its specific heat = 0.385 J/g.°C) was heated, its temperature rised by 10°C, **what is the amount of elevation in the temperature of 10 g of water** when they are provided by the same quantity of heat that copper acquired ?

.....

.....

.....

.....

.....

..... 2 marks

Exam model 6

Answered

Rate your level

Superior	Remarkable	above average	Weak
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	less than 10 marks

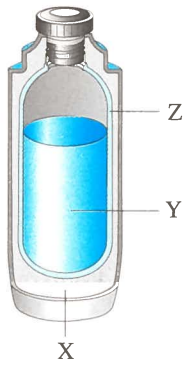
Choose the correct answer for the questions 1 : 10 ..... 10 marks

1 The change in heat content can be measured by using .....

(a) Hess's law. (b) the calorimeter.

(c) Hess's law or the calorimeter. (d) the thermometer.

2 Which of the following choices represents the system illustrated in the opposite figure ? .....



Choices	Type of the system	X	Y	Z
(a)	Closed	Copper	Hot liquid	Black surface
(b)	Isolated	Space	Cold liquid	White surface
(c)	Open	Plastic	Hot liquid	Coloured surface
(d)	Closed	Space	Hot or cold liquid	Silvered surface

3 The nucleus of ^{226}Ra isotope differs from that of ^{228}Ra isotope in the .....

(a) atomic number. (b) number of protons.

(c) number of neutrons. (d) number of electrons.

4 All the following radiations can lead to the ionization of water molecules, except .....

(a) alpha radiations. (b) gamma rays. (c) X-rays. (d) laser rays.

5 Each of methanol CH_3OH and octane C_8H_{18} combusts according to the following two equations :

- $2CH_3OH_{(\ell)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 4H_2O_{(\ell)}$ $\Delta H = -1450$ kJ
- $2C_8H_{18(\ell)} + 25O_{2(g)} \longrightarrow 16CO_{2(g)} + 18H_2O_{(\ell)}$ $\Delta H = -10900$ kJ

If the molar mass of methanol is 32 g/mol and that of octane is 114 g/mol..
Which of the following statements is more correct ? .....

(a) The quantity of heat produced from the combustion of 1 g of octane equals 96 kJ

(b) The quantity of heat produced from the combustion of 1 g of methanol equals 22.65 kJ

(c) The quantity of heat produced from the combustion of 1 kg of octane equals 9 times as that produced from the combustion of 1 kg of methanol.

(d) The quantity of heat produced from the combustion of methanol is not affected by the available amount of oxygen.

6 The following thermal equation shows the dissociation reaction of water :

$$2H_2O_{(\ell)} \longrightarrow 2H_{2(g)} + O_{2(g)} \qquad \Delta H = +571.8 \text{ kJ}$$

It shows that the process of formation of water from its constituent elements when they are in their standard states is .....

(a) an exothermic process releases a quantity of heat equals 571.8 kJ

(b) an exothermic process releases a quantity of heat equals 285.9 kJ

(c) an endothermic process absorbs a quantity of heat equals 571.8 kJ

(d) an endothermic process absorbs a quantity of heat equals 285.9 kJ

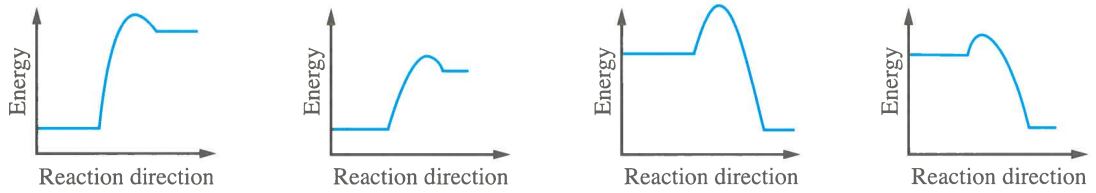
7 What is the pair of nuclei which contains the same number of neutrons ? .....

(a) ${}^{12}_{6}C$, ${}^{14}_{6}C$ (b) ${}^{23}_{11}Na$, ${}^{24}_{12}Mg$ (c) ${}^{16}_{7}N$, ${}^{16}_{8}O$ (d) ${}^{32}_{14}Si$, ${}^{32}_{15}P$

8 When ${}^{238}_{92}U$ nucleus loses an alpha particle to be transformed into a nucleus of thorium atom, which in turn transforms into a nucleus of protactinium atom when it loses a beta particle.. What is the symbol of the nucleus of the produced protactinium atom ? .....

(a) ${}^{230}_{90}Pa$ (b) ${}^{234}_{89}Pa$ (c) ${}^{234}_{90}Pa$ (d) ${}^{234}_{91}Pa$

9 Which of the following energy diagrams represents the thermal decomposition reaction which occurs in shorter time ? .....



(a) (b) (c) (d)

10 In terms of the thermochemical equation :

$$CH_{4(g)} \longrightarrow C_{(s)} + 4H_{(g)} \qquad \Delta H = +1648 \text{ kJ/mol}$$

What is the energy of the bond (C – H) ? .....

(a) +329.6 kJ/mol (b) +412 kJ/mol

(c) +1648 kJ/mol (d) +6592 kJ/mol

11 **Calculate the quantity of heat required** to raise the temperature of 1500 g of oil - before being used in frying potatoes - from 20°C to 180°C, knowing that the specific heat of the oil used is 1970 J/kg.°C

.....

.....

.....

..... 1 mark

12 The molar heat of solution of silver iodide is +84.4 kJ/mol

What do you conclude from the previous statement ?

.....

.....

..... 1 mark

13 **The opposite graph represents** the relation between the percentages of abundance of two isotopes of boron element and the relative atomic mass for each of them.

Calculate the atomic mass of boron element.

.....

.....

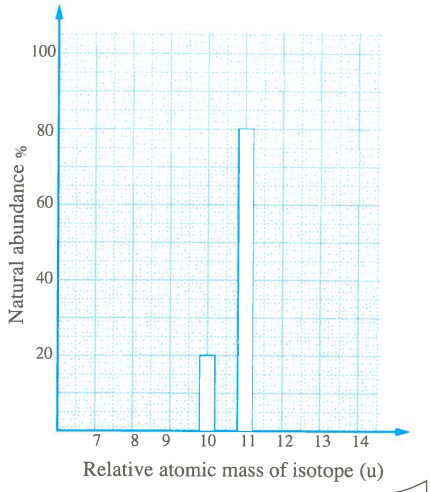
.....

.....

.....

.....

.....



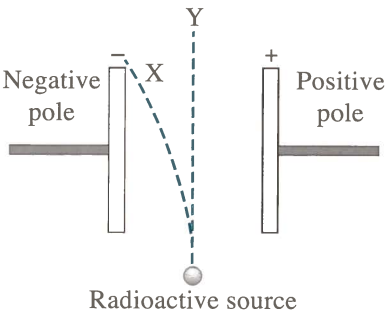
..... 1 mark

14 **The opposite figure represents** the path of two types of radiations emitted from a radioactive source in an electric field, **what is the type of each of (X) and (Y) radiations ? Explain why ?**

.....

.....

.....



..... 1 mark

15 The following reaction represents the formation process of butane gas from its elements :

$4C_{(s)} + 5H_{2(g)} \longrightarrow C_4H_{10(g)}$

Calculate the value of ΔH_f° of butane by knowing the standard heat of combustion (ΔH_c°) of the substances shown in the opposite table.

Substances	ΔH_c° (kJ/mol)
$C_{(s)}$	–393.5
$H_{2(g)}$	–285.85
$C_4H_{10(g)}$	–2877

.....

.....

.....

.....

.....

.....

..... / 2 marks

16 **Calculate the heat of combustion of 1 mol of methane gas according to the equation :** $CH_4 + 2O_2 \longrightarrow 2H_2O + CO_2$

By knowing the processes represented by the following thermochemical equations :

① $CH_4 \longrightarrow C + 4H$ $\quad \Delta H_1^\circ = +1663$ kJ/mol

② $O_2 \longrightarrow 2O$ $\quad \Delta H_2^\circ = +498$ kJ/mol

③ $H_2O \longrightarrow 2H + O$ $\quad \Delta H_3^\circ = +927$ kJ/mol

④ $CO_2 \longrightarrow C + 2O$ $\quad \Delta H_4^\circ = +1608$ kJ/mol

.....

.....

.....

.....

.....

.....

.....

.....

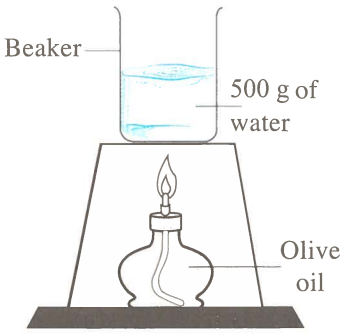
.....

.....

.....

..... / 2 marks

17 **The opposite figure represents** a heating process of 500 g of water by the produced thermal energy from the combustion of olive oil, by using the following table :



The initial temperature of water	21°C
ΔH of combustion of olive oil	−41 kJ/g
The quantity of heat lost	28 kJ

Calculate the final temperature of water after the complete combustion of 2.97 g of olive oil.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... 2 marks

Exam model 7

Answered

Choose the correct answer for the questions 1 : 10

..... / 10 marks

1 The term enthalpy is derived from the Greek word «enthalpen», which means .....

(a) warm. (b) hot.

(c) heat. (d) cold.

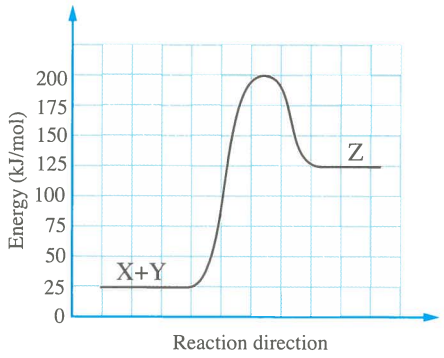
2 What is the percentage of the amount which is decayed from a radioactive substance after passing 5 half-life times of it ? .....

(a) 3.125% (b) 96.875%

(c) 31% (d) 0.3%

3 The opposite energy diagram represents the reaction : $X + Y \longrightarrow Z$

What is the value of the change in heat content of this reaction ? .....



(a) +100 kJ/mol

(b) +175 kJ/mol

(c) –100 kJ/mol

(d) –125 kJ/mol

4 The symbol ${}^{A}_{Z}X$ represents the nucleus of an unstable element and to reach the stability state it loses four β^--particles and an alpha particle, so the symbol of the nucleus of the produced element is .....

(a) ${}^{A+4}_{Z-2}Y$ (b) ${}^{A-4}_{Z+4}Y$ (c) ${}^{A-2}_{Z-4}Y$ (d) ${}^{A-4}_{Z+2}Y$

5 From the following equation : $2S_{(s)} + 3O_{2(g)} \longrightarrow 2SO_{3(g)}$ $\Delta H = -790$ kJ

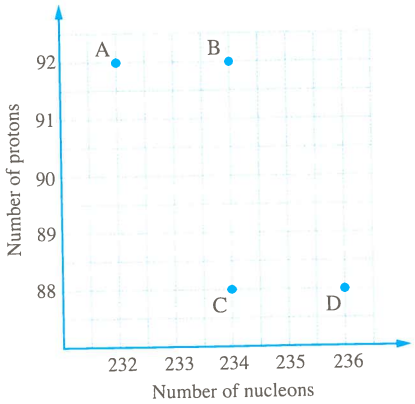
What is the value of the change in heat content of combustion of 0.972 g of sulphur ? ..... [S = 32]

(a) +23 kJ (b) –23 kJ

(c) –12 kJ (d) +12 kJ

6 $^{234}_{90}Th \xrightarrow{-\text{beta}} X \xrightarrow{-\text{beta}} Y$

In the opposite diagram,
Which letter represents element Y ? .....



(a) A (b) B
(c) C (d) D

7 On providing a piece of lead whose mass is 15 g with a quantity of heat equals 29 J , its temperature increases from 22°C to 37°C , What is the specific heat of lead ? .....

(a) 7.8 J/g.°C (b) 1.92 J/g.°C (c) 29 J/g.°C (d) 0.129 J/g.°C

8 Radiations produced from radioactive isotopes are used in all the following, except .....

(a) destroying cancer cells.
(b) fertilizing female insects.
(c) causing mutations in embryos.
(d) preserving strawberry from spoiling.

9 In the following reaction :

$$Ni_{(s)} + 2CO_{(g)} + 2PF_{3(g)} \longrightarrow Ni(CO)_2(PF_3)_{2(\ell)}$$

Which of the following choices its ΔH_f° equals zero ? .....

(a) $Ni_{(s)}$ (b) $CO_{(g)}$
(c) $PF_{3(g)}$ (d) $Ni_{(s)}$ and $CO_{(g)}$

10 From the following reaction and the opposite table :

$$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$$

Bond	Average bond energy (kJ/mol)
Cl – Cl	240
H – H	432
H – Cl	430

We conclude that .....

(a) ΔH of the reaction equals +1442 kJ
(b) ΔH of the reaction equals +348 kJ
(c) the energy produced from forming 1 mol of products equals –94 kJ/mol
(d) the energy produced from forming 1 mol of products equals –188 kJ/mol

11 **Arrange the following compounds ascendingly according to their thermal stability :**

The compound	$NO_{(g)}$	$NO_{2(g)}$	$N_2O_{(g)}$	$N_2O_{4(g)}$
ΔH_f° (kJ/mol)	+90.4	+33.85	+81.56	+9.66

.....

..... 1 mark

12 **Calculate the molar heat of solution of sodium chloride salt, from the following two equations :**

- $NaCl_{(s)} \longrightarrow Na^+_{(g)} + Cl^-_{(g)}$ $\Delta H = +788$ kJ/mol
- $Na^+_{(g)} + Cl^-_{(g)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$ $\Delta H = -784$ kJ/mol

.....

.....

.....

..... 1 mark

13 **Why** is it impossible for the isotope ^2_2He to exist in nature ?

.....

.....

.....

..... 1 mark

14 **What is the difference between** the natural transmutation reactions of the elements and the elemental transmutation reactions ?

.....

.....

.....

.....

.....

..... 1 mark

15 **Replace letter X in each equation by what it represents actually :**

(1) $^{59}_{27}Co + {}^{2}_{1}H \longrightarrow {}^{60}_{27}Co + X$ (.....)

(2) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{94}_{36}Kr + {}^{139}_{56}Ba + 3X$ (.....)

(3) $^{20}_{8}O \longrightarrow {}^{20}_{9}F + X$ (.....)

(4) $^{59}_{27}Co + {}^{1}_{0}n \longrightarrow {}^{56}_{25}Mn + X$ (.....)

..... / 2 marks

16 **Calculate the nuclear binding energy per nucleon** in the nucleus of iodine isotope $^{127}_{53}I$, **knowing that** its actual mass is 126.9004 u , the mass of proton is 1.00728 u and the mass of neutron is 1.00866 u

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... / 2 marks

17 **Calculate the quantity of heat released** on burning 87.9 g of sulphur dioxide (its molar mass is 64 g/mol), according to the following thermochemical equation :

$$2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)} \qquad \Delta H = -198.2 \text{ kJ}$$

.....

.....

.....

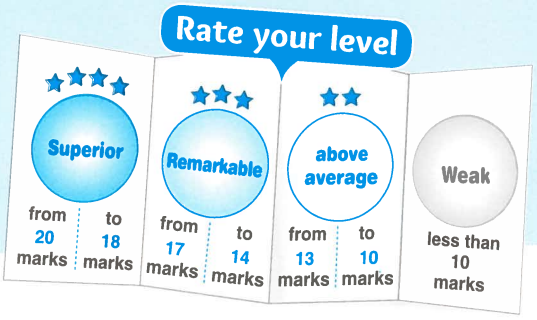
.....

.....

..... / 2 marks

Exam model 8

Answered



Choose the correct answer for the questions 1 : 10

10 marks

1 Which of the following choices expresses correctly the reaction represented by the following equation ? .....

$C_2H_5OH_{(\ell)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(\ell)}$ $\quad \Delta H = -1.37 \times 10^3$ kJ/mol

(a) The reaction is exothermic and ΔH value is different when the product is $H_2O_{(v)}$

(b) The reaction is exothermic and there is no oxidation-reduction reaction.

(c) The reaction is exothermic and the volume of the produced gases is larger than the volume of the reacting gases.

(d) The reaction is endothermic and the volume of the produced gases is less than the volume of the reacting gases.

2 What is the quantity of heat required to raise the temperature of a mass of iron equals 5.75 g (its specific heat is 0.45 J/g.°C) from 25°C to 79.8°C ? .....

(a) 315 kJ

(b) 2.54 J

(c) 141.8 kJ

(d) 141.8 J

3 When 0.236 mol of a weak base reacts with excess HCl acid, a quantity of energy equals 6.91 kJ is released.. What is the value of ΔH of the reaction in kJ/mol ? .....

(a) +34.2

(b) –34.2

(c) –29.3

(d) +29.3

4 In terms of the following reactions :

- $2A \longrightarrow \frac{1}{2}B + C$ $\quad \Delta H_1 = +5$ kJ
- $\frac{3}{2}B + 4C \longrightarrow 2A + C + 3D$ $\quad \Delta H_2 = -15$ kJ
- $E + 4A \longrightarrow C$ $\quad \Delta H_3 = +10$ kJ

What is the value of ΔH of the reaction : $C \longrightarrow E + 3D$? .....

(a) +10 kJ

(b) –10 kJ

(c) –20 kJ

(d) +20 kJ

5 Which of the following its standard heat of formation does not equal zero (at 25°C) ? .....

(a) $F_{2(g)}$ (b) $Al_{(s)}$ (c) $Hg_{(\ell)}$ (d) $CO_{2(g)}$

6 What does symbol X represent in the equation : $^{238}_{92}U \longrightarrow {}^{4}_{2}He + X$? .....

(a) $^{242}_{94}Pu$ (b) $^{234}_{90}Th$

(c) $^{242}_{90}Th$ (d) $^{234}_{92}U$

7 The ratio between the diameter of the atom to that of the nucleus is approximately .....

(a) $1 : 10^{-5}$ (b) $1 : 10^{5}$

(c) $1 : 10^{2}$ (d) $1 : 10^{15}$

8 Iron-59 isotope lies at the left side of the belt of stability.. What is the expected emission produced from it ? .....

(a) Beta particle. (b) Positron.

(c) Alpha particle. (d) Gamma rays.

9 What is the time required for decaying 53.125% of the nuclei of a radioactive element, its half-life is 32 min ? .....

(a) 21 min (b) 30 min

(c) 34 min (d) 42 min

10 When the nucleus of $^{106}_{46}Pd$ is bombarded with an alpha particle, a proton is emitted and a new element is formed which is .....

(a) $^{112}_{48}Cd$ (b) $^{109}_{48}Cd$

(c) $^{108}_{47}Ag$ (d) $^{109}_{47}Ag$

11 **What is the physical property** which makes the liquified ammonia more preferable than water to be used as a heat exchange substance in the bomb calorimeter ?

.....

.....

..... 1 mark

12 To prepare four cups of tea we need to heat an amount of water from 35°C to 100°C through providing it with a quantity of heat equals 218400 J, **calculate the used amount of water in grams.**

.....

.....

.....

..... / 1 mark

13 **Calculate the mass** of $^{235}_{92}U$ nucleus, if you know that the average of nucleon mass = 1.7×10^{-10} kg

.....

.....

.....

..... / 1 mark

14 Magnetic and electric fields of the radiations emitted from the laptop when operated, cause an elevation in the temperature of the body cells which are in contact with it.. **What** are these radiations ?

And what is the possible harmful effect of using the laptop as shown in the opposite figure ?

.....

.....

..... / 1 mark

15 **Europium ($_{63}Eu$) element is used in TV screens to enhance the resolution and it has two isotopes as illustrated in the following table :**

Isotope	Relative atomic mass	Abundance in nature
^{151}Eu	151 u	47.77%
^{153}Eu	153 u	52.23%

(1) What are the similarity **and** the difference between (^{151}Eu) and (^{153}Eu) ?

.....

.....

(2) **Calculate** the atomic mass of europium element.

.....

.....

.....

.....

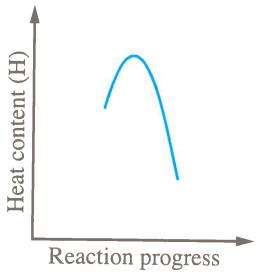
.....

..... 2 marks

16 **Aluminum reacts vigorously with iron (III) oxide forming aluminum oxide and iron with releasing a large quantity of heat energy :**

(1) **Write** the symbolic chemical equation which represents this reaction.

.....



(2) **Complete** the opposite energy diagram, with writing labels and illustrating the enthalpy change.

..... 2 marks

17 The combustion of ethanol occurs according to the following equation :

$$C_2H_5OH_{(\ell)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(\ell)} \qquad \Delta H_c^\circ = ?$$

Calculate the change in the standard combustion enthalpy of ethanol assisted by the following table :

Alcohol	The number of carbon atoms in alcohol	The change in combustion enthalpy ΔH_c°
1–butanol C_4H_9OH	4	– 2678 kJ/mol
1–pentanol $C_5H_{11}OH$	5	– 3331 kJ/mol

.....

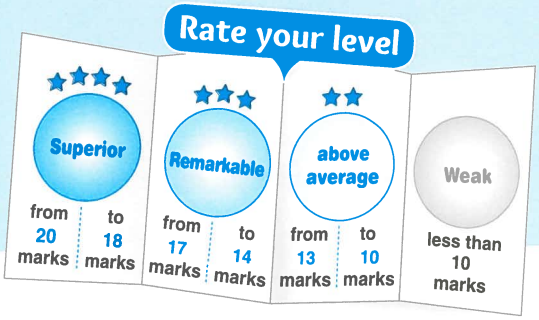
.....

.....

..... 2 marks

Exam model 9

Answered



Choose the correct answer for the questions 1 : 10

..... 10 marks

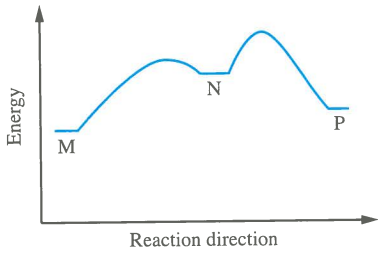
1 The human body represents .....

(a) a closed system.
(b) an open system.
(c) an isolated system.
(d) no correct answer.

2 Three types of radiations are emitted from the unstable nuclei which can be represented by the electron, the helium nucleus and the electromagnetic radiation.. Which of the following choices represents them correctly and respectively ? .....

Choices	Electron	Helium nucleus	Electromagnetic radiation
(a)	Alpha	Beta	Gamma
(b)	Alpha	Gamma	Beta
(c)	Beta	Alpha	Gamma
(d)	Beta	Gamma	Alpha

3 The opposite energy diagram represents one of the chemical reactions in which an enzyme is used as a catalyst.. Which one of the following statements is correct ? The change in the heat content from .....



M: Reactants.
N: Intermediate compound.
P: Products.

(a) M to N is exothermic and from N to P is exothermic.
(b) M to P is exothermic and from N to P is endothermic.
(c) M to N is endothermic and from N to P is endothermic.
(d) M to N is endothermic and from M to P is endothermic.

4 Which of the following equations represents a reaction which is probably occurs in a nuclear fission reactor ? .....

(a) ${}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n$
(b) ${}^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{15}_{7}N$
(c) ${}^{46}_{21}Sc \longrightarrow {}^{46}_{21}Sc + \gamma$
(d) ${}^{238}_{92}U + {}^{1}_{0}n \longrightarrow {}^{95}_{38}Sr + {}^{141}_{54}Xe + 3{}^{1}_{0}n$

5 The following reaction represents the combination of hydrogen gas with oxygen gas to form water :

$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$

What is the value of ΔH of that reaction ? .....

Bond	Average bond energy (kJ/mol)
H–H	436
O=O	499
H–O	464

(a) +464 kJ (b) – 485 kJ

(c) +485 kJ (d) 0

6 The natural transformation of $^{238}_{92}U$ nucleus to $^{234}_{91}Pa$ nucleus occurs in two steps, due to the emission of .....

(a) $\alpha + \beta^-$ (b) $\alpha + \gamma$

(c) $2\beta^-$ (d) $\beta^- + \gamma$

7 What is the value of ΔH of the reaction : $CO_{(g)} + 2H_{2(g)} \longrightarrow CH_3OH_{(v)}$ $\Delta H = -91$ kJ if $CH_3OH_{(\ell)}$ is formed instead of $CH_3OH_{(v)}$, knowing that ΔH of CH_3OH vaporization equals +37 kJ/mol ? .....

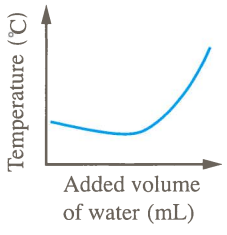
(a) –128 kJ (b) –54 kJ (c) +128 kJ (d) +54 kJ

8 A sample of a radioactive element whose half-life equals 10 min and it contains at that moment 2000 nuclei..

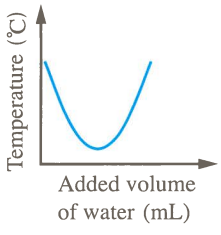
What is the number of nuclei in this sample half an hour ago ? .....

(a) 250 nuclei. (b) 4000 nuclei. (c) 6000 nuclei. (d) 16000 nuclei.

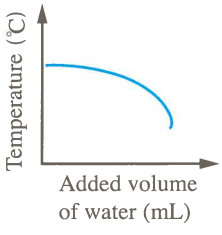
9 On dissolving salts in water, the molecules of each of solute and solvent are separated, then the attraction (combination) occurs between the solute ions and water molecules.. Which of the following graphical figures represents the change in the temperature on dissolving ammonium nitrate salt in water ? .....



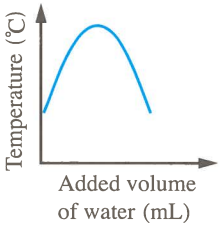
(a)



(b)



(c)



(d)

10 **Silver exists in nature as a mixture of two isotopes ^{107}Ag and ^{109}Ag, if you know that the atomic number of silver is 47 and its atomic mass is 108, what is the statement which expresses correctly the silver isotopes ?** .....

(a) Atomic mass of all silver atoms is 108

(b) The abundance percentage of ^{107}Ag isotope is greater than that of ^{109}Ag isotope.

(c) Atoms of both ^{107}Ag and ^{109}Ag form positive ions which have the same charge.

(d) Atoms of both ^{107}Ag and ^{109}Ag contain the same number of neutrons.

11 **Calculate the quantity of heat released** on formation of 2.8 g of aluminum fluoride (whose molar mass = 81 g/mol) from its constituent elements, knowing that its heat of formation equals –216 kJ/mol

.....

.....

.....

.....

..... / 1 mark

12 **Calculate the mass of the nucleus** of copper-65 isotope (in kg), knowing that its atomic mass equals 64.9278 amu

.....

.....

.....

..... / 1 mark

13 The following equation indicates the total reaction of the conversion of methane CH_4 to methanol CH_3OH $\quad CH_{4(g)} + \frac{1}{2} O_{2(g)} \longrightarrow CH_3OH_{(\ell)}$

Calculate ΔH value of the reaction, knowing that the standard heat of formation of each of methane and methanol equals –75 kJ/mol and –239 kJ/mol respectively.

.....

.....

.....

.....

..... / 1 mark

14 **Prove mathematically that** the neutron is electrically neutral (zero), in the light of your knowledge of quarks.

.....

.....

.....

..... / 1 mark

15 «An ionic compound whose negative value of ΔH_{sol} in water is very high»..

Is this compound sparingly soluble in water **or** highly soluble in water ?

With giving reason.

.....

.....

.....

.....

.....

.....

.....

.....

..... / 2 marks

16 The following fusion reaction occurs in the sun : $4\,{}^{1}_{1}H \longrightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}e$

Calculate the heat released from the nuclear fusion in (J) and (MeV), knowing that the binding energy per nucleon in each of ${}^{1}_{1}H$ and ${}^{4}_{2}He$ equals zero and 7.2 MeV respectively.

.....

.....

.....

.....

.....

..... / 2 marks

17 Lattice enthalpy ΔH_l is defined as the heat change that accompanies the conversion of 1 mol of the crystal lattice of an ionic compound into ions..

Use the data shown in the opposite table to calculate the lattice enthalpy of sodium chloride.

	The process	ΔH (kJ/mol)
①	$Na_{(s)} \longrightarrow Na_{(g)}$	+109
②	$Na_{(g)} \longrightarrow Na^+_{(g)} + e^-$	+494
③	$Cl_{2(g)} \longrightarrow 2Cl_{(g)}$	+242
④	$Cl_{(g)} + e^- \longrightarrow Cl^-_{(g)}$	–364
⑤	$Na_{(s)} + \frac{1}{2}Cl_{2(g)} \longrightarrow NaCl_{(s)}$	–411

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

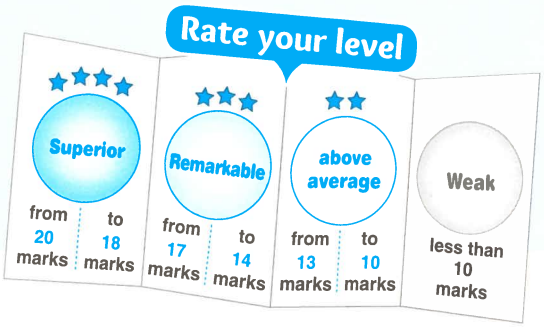
.....

.....

2 marks

Exam model 10

Answered



Choose the correct answer for the questions 1 : 10

..... / 10 marks

1 When the isotope $^{238}_{93}Np$ loses a beta particle, ... is formed.

(a) $^{238}_{92}U + \beta^-$
(b) $^{238}_{94}Pu + {}^{0}_{-1}e$
(c) $^{238}_{92}U + \beta^+$
(d) $^{238}_{94}Np + \beta^-$

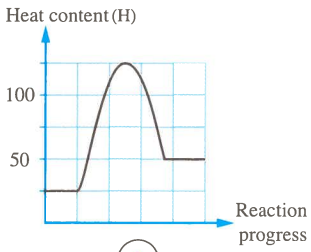
2 Two pieces of two different metals both have the same mass and initial temperature are provided with the same amount of thermal energy.. Which of them its temperature rises by a lower value ? .....

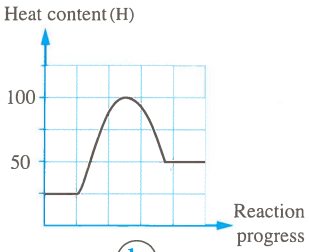
(a) The metal whose specific heat is higher.
(b) The metal whose specific heat is lower.
(c) The metal whose density is higher.
(d) The metal whose volume is smaller.

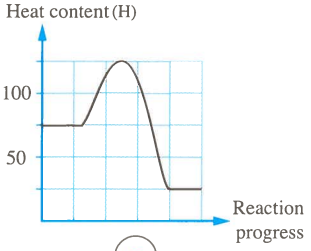
3 The nucleus of $^{12}_{7}N$ isotope is unstable and lies at the right side of the belt of stability. To reach to the stability state, ... is emitted from it.

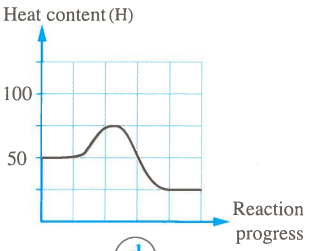
(a) $^{0}_{-1}e$
(b) α
(c) γ
(d) $^{0}_{+1}e$

4 Which of the following diagrams represents an exothermic reaction which has lower ΔH value ? .....

(a)


(b)


(c)


(d)


5 Nucleus of radon atom is expressed by the symbol $^{222}_{86}Rn$.. Which of the following choices represents the number of particles in radon atom ? .....

Choices	Electrons	Protons	Neutrons
(a)	136	86	222
(b)	136	136	86
(c)	86	86	136
(d)	222	222	86

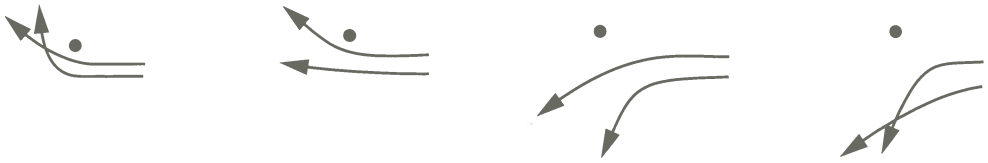
6 From the two following thermochemical equations :

- $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(v)}$ $\Delta H = -900$ kJ/mol
- $H_2O_{(\ell)} \longrightarrow H_2O_{(v)}$ $\Delta H = +44$ kJ/mol

What is the maximum mass of water [H_2O = 18 g/mol] that can be converted into water vapour using the energy released from the combustion of 1 mol of methane gas CH_4 ? .....

(a) 20.5 g (b) 61.8 g (c) 184 g (d) 368 g

7 Which of the following figures represents the path of two rays of alpha particles when approaching a large nucleus ? .....



(a) (b) (c) (d)

8 Which of the following reactions has ΔH value opposite in sign to the other reactions ? .....

(a) $I_{2(s)} \longrightarrow I_{2(v)}$ (b) $Na^+_{(g)} + e^- \longrightarrow Na_{(g)}$

(c) $CO_{2(g)} \longrightarrow C_{(s)} + O_{2(g)}$ (d) $2NaCl_{(\ell)} \longrightarrow 2Na_{(s)} + Cl_{2(g)}$

9 Copper is found in the form of two isotopes which are ^{63}Cu and ^{65}Cu, knowing that the atomic mass of copper equals 63.5 u

What is the ratio of abundance of ^{63}Cu : ^{65}Cu isotopes in nature ? .....

(a) 63 : 65 (b) 3 : 1 (c) 1 : 3 (d) 1 : 1

10 **What is the amount of energy released on the complete combustion of methane that is found in 1 kg of crystallized methane $CH_4.6H_2O$, knowing that the heat of combustion of methane is (–889 kJ/mol) ?** ..... [C = 12 , H = 1 , O = 16]

(a) 8.89×10^2 kJ (b) 7.17×10^3 kJ (c) 4.3×10^4 kJ (d) 5.56×10^4 kJ

11 **Calculate the remained mass** from 6 g of a radioactive element, whose half-life is 78 days after passing 312 days.

.....

.....

..... 1 mark

12 **Calculate the quantity of energy** produced from the conversion of 0.5 g of a substance in Joules.

.....

..... 1 mark

13 **Calculate ΔH of the reaction :** $NH_{3(g)} + CH_{4(g)} \longrightarrow 3H_{2(g)} + HCN_{(g)}$

By knowing the following equations :

① $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$ $\Delta H_1 = -91.8$ kJ

② $C_{(s)} + 2H_{2(g)} \longrightarrow CH_{4(g)}$ $\Delta H_2 = -74.9$ kJ

③ $H_{2(g)} + 2C_{(s)} + N_{2(g)} \longrightarrow 2HCN_{(g)}$ $\Delta H_3 = +270.3$ kJ

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... 1 mark

14 **Deduce the number of neutrons and electrons in the atom of element X which is produced from the following fission reaction :** $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{A}_{Z}X + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n$

.....

.....

.....

.....

..... / 1 mark

15 **Calculate the least number of ice pieces** required to cool 500 g of water (its specific heat is 75.4 J/mol.°C) from 20°C to 0°C, knowing that the enthalpy change of melting the ice piece equals 6.02 kJ/mol and each ice piece contains 1 mol of water. [H_2O = 18 g/mol]

.....

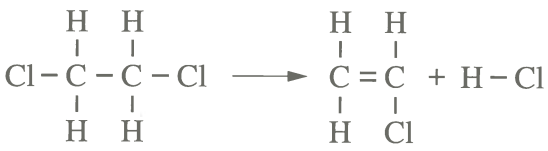
.....

.....

.....

..... / 2 marks

16 **Calculate the change in heat content for the following reaction :**



By knowing the average bond energies shown in the opposite table.

The bond	Average bond energy (kJ/mol)
C–H	413
C–C	347
C=C	612
C–Cl	346
H–Cl	432

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... / 2 marks

17 **Antimony has 29 isotopes, only two of them are stable which are $^{121}_{51}Sb$ and $^{123}_{51}Sb$ while the others are unstable :**

(1) How can you prove mathematically that the isotope $^{121}_{51}Sb$ is stable ?

.....

.....

.....

.....

.....

(2) A beta particle is emitted from the nucleus of antimony $^{117}_{51}Sb$ atom forming the nucleus of tellurium atom (Te)..

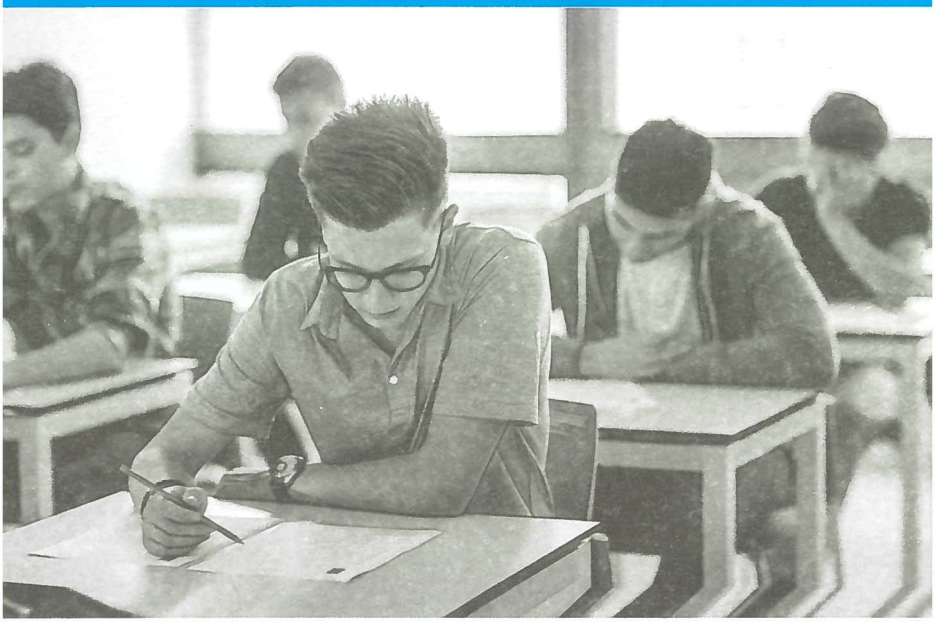
Write the nuclear equation that represents this emission.

.....

.....

..... 2 marks

Suggested answers



Steady Answers of open book questions about each lesson.

Go Answers of the examination models.

Answers of Unit 4 Chapter One Lesson 1

1 (c)	2 (b)	3 (c)	4 (d)
5 (a)	6 (d)	7 (a)	8 (d)
9 (c)	10 (c)	11 (b)	12 (c)
13 (c)	14 (c)	15 (d)	16 (b)
17 (a)			

N.B

The ideas of the questions marked by the mark ○ will be clarified right below the choices

Ideas of answering the questions marked by the mark ○

Question number	Idea of answering
11	The specific heat is a characteristic property for each substance, as it is a constant value that does not change by changing its mass or temperature. ∴ The correct choice is (b)
12	$c_1 = \frac{q_{p_1}}{m_1 \Delta T_1}$, $c_2 = \frac{q_{p_2}}{m_2 \Delta T_2}$ $\because m_1 = m_2$, $q_{p_1} = q_{p_2}$, $\Delta T_2 = 2\Delta T_1$ $\therefore c_2 = \frac{q_{p_1}}{m_1 \times 2\Delta T_1} = \frac{1}{2} c_1$ ∴ The correct choice is (c)
16	$q_p = m c \Delta T$ $q_{(absorbed)} = 100 \times 4.18 \times (T - 15)$ $q_{(lost)} = 250 \times 4.18 \times (T - 50)$

$\because q_{(absorbed)} = - q_{(lost)}$

$\therefore [100 \times 4.18 \times (T - 15)] = - [250 \times 4.18 \times (T - 50)]$

$[418\ T - 6270] = - [1045\ T - 52250]$

$418\ T + 1045\ T = 6270 + 52250$

$1463\ T = 58520 \qquad \therefore T = 40^{\circ}C$

$\therefore$ The correct choice is (b)

18 (1) By removing the plug from the mouth of the bottle.
(2) By putting the bottle in a closed thermal insulating vessel.

19 0.488 J/g.°C / Because specific heat is a characteristic property for the substance, it does not change by changing its mass.

20 $c = \frac{q_p}{m\Delta T} = \frac{700}{(1 \times 1000) \times 1} = 0.7$ J/g.°C

This means that the specific heat of this substance is 0.7 J/g.°C

21 The specific heat of the same substance (water) differs according to the physical state of this substance.

22 Because the specific heat of aluminum is lower than that of water.

23 (1) The sand / Because its specific heat is lower than that of water, consequently its temperature rises more by acquiring the same quantity of heat.
(2) Water / Because its specific heat is higher than that of the sand, consequently its temperature takes more time to decrease.

24 (1) The temperature of iron rises more than that of water.
(2) The temperature of water rises by the amount of energy produced from the burning process in the isolated system.

25 Yes / Because the density of water equals 1 g/cm^3

26

$$q_p = mc\Delta T$$

$$c\ (J/g.°C) = \frac{1970}{1000} = 1.97\ J/g.°C$$

$$q_p = 1500 \times 1.97 \times (180 - 20) = 472800\ J$$

27 $q_p = 500 \times 2.42 \times (44.1 - 20.2) = 28919\ J$

28 $q_p = 40 \times 4.18 \times 20 = 3344\ J$

$$c_{oil} = \frac{q_p}{m\Delta T} = \frac{3344}{30 \times 70} = 1.59\ J/g.°C$$

29

$$\Delta T = \frac{q_p}{mc}$$

$$T_2 = \Delta T + T_1$$

* **For the sand :**

$$\Delta T_{(sand)} = \frac{65000}{6 \times 840} = 12.897°C\ ,\ T_{2\,(sand)} = 12.897 + 20 = 32.897°C$$

* **For water :**

$$\Delta T_{(water)} = \frac{65000}{6 \times 4180} = 2.59°C\ ,\ T_{2\,(water)} = 2.59 + 20 = 22.59°C$$

* **Conclusion :** The elevation in the temperature of the substance with the higher specific heat (water) is lower than the elevation in the temperature of the substance with the lower specific heat (sand) when two equal masses of them (6 kg) acquire the same quantity of heat (65000 J).

Answers of the new types of questions

1 (a) , (d) **2** (b) , (e) **3** (c) , (e)

4
- **The kettle :** Its mass decreases by time.
- **The pressure cooker :** An isolated system.

Answers of Unit 4 Chapter One Lesson 2

1 (d)	2 (b)	3 (a)	4 (b)
5 (b)	6 (c)	7 (d)	8 (d)
9 (b)	10 (a)	11 (c)	12 (d)
13 (b)	14 (a)	15 (b)	16 (a)
17 (b)	18 (c)	19 (c)	20 (d)
21 (b)	22 (b)	23 (c)	24 (c)

N.B

The ideas of the questions marked by the mark ○ will be clarified right below the choices

Ideas of answering the questions marked by the mark ○

Question number	Idea of answering
5	$N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)}$ According to the equation, 1 mol of N_2 gas combines with 2 mol of O_2 gas, forming 2 mol of NO_2 gas, when 2 mol of N_2 are mixed with 2 mol of O_2 , still 2 mol of NO_2 will be formed, and 1 mol of N_2 will remain, and the change in enthalpy remains the same +66 kJ ∴ The correct choice is (b)
11	∵ The thermal decomposition reaction is endothermic. **i.e.** the heat contents of the products are larger than those of the reactants. ∴ The choices (a) and (b) are excluded. ∵ The quantity of heat absorbed to convert the reactants into the products in the choice (c) is lower than that in the choice (d) ∴ The choice (d) is excluded. ∴ The correct choice is (c)

19

In step (1) : The bonds between each of hydrogen molecules, and in the molecule of oxygen are broken to form free atoms, and this process is endothermic.

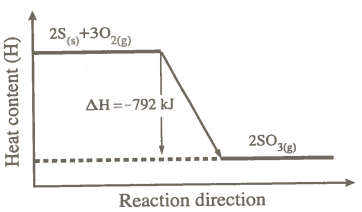
$\therefore$ The choices (b) and (d) are excluded.

In step (3) : Water vapour $H_2O_{(v)}$ is converted into liquid water $H_2O_{(\ell)}$ by condensation, and this process is exothermic.

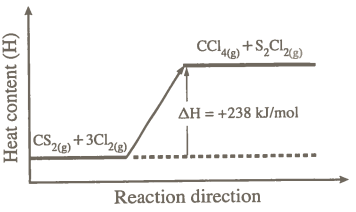
$\therefore$ The choice (a) is excluded.

$\therefore$ The correct choice is (c)

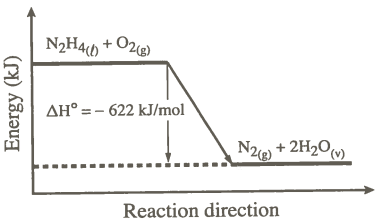
25 (1)



(2)

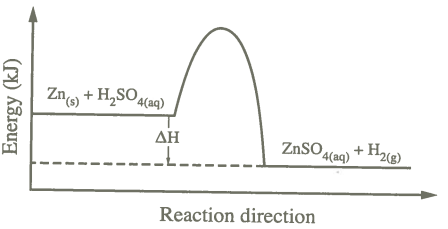


26 (1)



(2) Reaction (2) / Because the quantity of heat produced from this reaction is larger than that produced from reaction (1).

27 **(1)**



(2) Exothermic / Because the heat contents of the products are lower than those of the reactants.

28 Exothermic reaction / Because the amount of the released energy during the formation of the products bonds (XY) is larger than the amount of the absorbed energy during breaking the reactants bonds (X_2 , Y_2).

ΔH = Energy absorbed during breaking the reactants bonds + Energy released during the formation of the products bonds

29 * Energy absorbed during breaking the reactants bonds

$= [(H - H) + (Br - Br)] = 432 + 193 = +625$ kJ

* Energy released during the formation of the products bonds

$= [2(H - Br)] = 2 \times (-366) = -732$ kJ

$\Delta H = (+625) + (-732) = -107$ kJ

30 $(H - C \equiv C - H) + \frac{5}{2}(O = O) \xrightarrow{\Delta} 2(O = C = O) + (H - O - H)$

* Energy absorbed during breaking the reactants bonds

$= [2(C - H) + (C \equiv C) + \frac{5}{2}(O = O)] = [(2 \times 413) + 835 + (\frac{5}{2} \times 498)]$

$= +2906$ kJ

* Energy released during the formation of the products bonds

$= [2 \times 2(C = O) + 2(O - H)] = [(4 \times -803) + (2 \times -467)]$

$= -4146$ kJ

$\Delta H = (+2906) + (-4146) = -1240$ kJ

31 **(1)** * Energy absorbed during breaking the reactants bonds

$= [(H - H) + (Cl - Cl)] = [104 + 58] = +162$ kcal

* Energy released during the formation of the products bonds

$= [2(H - Cl)] = [2 \times (-103)] = -206$ kcal

ΔH (kcal) $= (+162) + (-206) = -44$ kcal

ΔH (kJ) $= -44 \times 4.18 = -183.92$ kJ

(2) Exothermic / Because the amount of energy released during the formation of the products bonds is larger than that absorbed during breaking the reactants bonds.

(3) Answer it yourself.

---

32 **(1)** Energy absorbed during breaking the bonds in 1 mol of the compound

$= [3(C - F) + (C - C) + 3(C - Cl)]$

$= [(3 \times 450) + 346 + (3 \times 340)] = +2716$ kJ

(2) Because the energy of ultraviolet rays is higher than the average (C – Cl) bond energy, and it is lower than the average (C – F) bond energy.

---

33 * Energy absorbed during breaking the reactants bonds

$= [(N \equiv N) + 3(H - H)] = [941 + (3 \times 432)] = +2237$ kJ

* Energy released during the formation of the products bonds

$= [2 \times 3(N - H)]$

$\therefore -89 = (+2237) - [6(N - H)]$

$6(N - H) = 2237 + 89 = 2326$ kJ

$(N - H) = \frac{2326}{6} = 387.67$ kJ/mol

34 * Energy absorbed during breaking the reactants bonds

$= [2 \times 2(S = O) + (O = O)]$

$= [(4 \times 534) + 498] = +2634$ kJ

* Energy released during the formation of the products bonds

$= [2 \times 3\ (S = O)]$

$\therefore -196 = (+2634) - [6(S = O)]$

$6(S = O) = 2634 + 196$

$= 2830$ kJ

$\therefore$ The average bond energy of (S = O) in SO_3 molecule

$= \frac{2830}{6} = 471.67$ kJ/mol

$\therefore$ The average bond energy of (S = O) in SO_3 molecule is different from its average bond energy in SO_2 molecule.

Answers of the new types of questions

1 (b), (c) 2 (a), (d) 3 (A): 5 (B): 3

Answers of Unit 4 Chapter Two Lesson 1

1 (d)	2 (a)	3 (a)
4 (a)	5 (c)	6 (c)
7 (b)	8 (c)	9 (a)
10 (a)	11 (d)	

N.B
The ideas of the questions marked by the mark ○ will be clarified right below the choices

Ideas of answering the questions marked by the mark ○

Question number	Idea of answering
2	$m_{(solution)} = m_{(solute)} + m_{(solvent)} = 8 + 125 = 133$ g $q_p = m c \Delta T$ $= 133 \times 4.2 \times (18.2 - 24.2) = -3351.6$ J $= -3.3516$ kJ Molar mass of $NH_4NO_3 = 14 + (1 \times 4) + 14 + (16 \times 3) = 80$ g/mol No. of moles of $NH_4NO_3 = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$ $= \frac{8}{80} = 0.1$ mol $\Delta H_{sol} = \frac{-q_p}{n} = \frac{-(-3.3516)}{0.1} = +33.5$ kJ/mol ∴ The correct choice is (a)
10	∵ ΔH°_{sol} in both reactions is positive. ∴ Both reactions are endothermic. **In reaction (1) :** Hydration energy is less than the separation energy of the solute molecules by 25.7 kJ/mol, which is a large amount. ∴ The choices (c) and (d) are excluded. **In reaction (2) :** Hydration energy is less than the separation energy of the solute molecules by 0.9 kJ/mol, which is a small value equals approximately 1 ∴ The choice (b) is excluded. ∴ The correct choice is (a)

12 **(1)** (A / Solvent) , (B / Solute) , (C / Solution).

(2) Endothermic / Due to absorbing an amount of energy to overcome the attraction forces between the solute molecules.

(3) Solution is exothermic.

13 Molar mass of NaCl = 23 + 35.5 = 58.5 g/mol

$$\text{Number of moles (n)} = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{58.5}{58.5} = 1 \text{ mol}$$

Because it is produced from dissolving 1 mol of NaCl in an amount of the solvent to form 1 liter of sodium chloride solution.

14 $CaF_{2(s)} \xrightarrow{\text{water}} Ca^{2+}_{(aq)} + 2F^-_{(aq)}$ $\qquad \Delta H^\circ_{sol} = -51$ kJ/mol

15

$CaCl_2$	$\longrightarrow$	ΔH_{sol}
1.1 g		−0.8 kJ
40 + (2 × 35.5) = 111 g/mol		? kJ/mol

∴ Molar heat of solution of calcium chloride ($CaCl_2$) $= \frac{-0.8 \times 111}{1.1}$

$= -80.73$ kJ/mol

16

KOH	$\longrightarrow$	ΔH_{sol}
39 + 16 + 1 = 56 g/mol		−58.5 kJ/mol
2.8 g		? kJ

∴ Change in heat content produced from dissolving 2.8 g of KOH

$= \frac{-58.5 \times 2.8}{56} = -2.925$ kJ

17 $q_p = m\ c\ \Delta T$

$= 1000 \times 4.18 \times 2.3 = 9614$ J $= 9.614$ kJ

Number of dissolved moles of LiBr (n) $= \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$

$= \frac{17.368}{86.84} = 0.2$ mol

$\Delta H_{sol} = \frac{-q_p}{n} = \frac{-9.614}{0.2} = -48.07$ kJ/mol

---

18 **(1)** $q_p = m\ c\ \Delta T$

$= 1000 \times 4.18 \times (16.17 - 25) = -36909.4\ J = -36.9$ kJ

Molar mass of $AgNO_3 = 108 + 14 + (3 \times 16) = 170$ g/mol

Number of moles of $AgNO_3 = \frac{170}{170} = 1$ mol

$\Delta H^\circ_{sol} = \frac{-q_p}{n} = \frac{-(-36.9)}{1} = 36.9$ kJ/mol

(2) Yes / The heat change accompanying this solution represents the molar heat of solution, because :

- Number of moles of solute (silver nitrate) = 1 mol
- Volume of the produced solution = 1 L

Answers of the new types of questions

1 (b) , (d) **2** (b) , (d) **3** **(1)** : (e) **(2)** : (b)

Answers of Unit 4 Chapter Two Lesson 2

1 (c)	**2** (c)	**3** (d)	**4** (b)
5 (a)	**6** (c)	**7** (a)	**8** (b)
9 (d)	**10** (b)	**11** (c)	**12** (d)
13 (a)	**14** (b)	**15** (d)	**16** (b)
17 (d)	**18** (b)	**19** (b)	**20** (b)
21 (c)	**22** (b)	**23** (a)	**24** (b)
25 (b)	**26** (d)	**27** (a)	

N.B

The ideas of the questions marked by the mark will be clarified right below the choices

Ideas of answering the questions marked by the mark ○

Question number	Idea of answering
5	* Heat of combustion of 1 g of each fuel is calculated.

The choice	Heat of combustion ΔH_c produced from burning 1 g of each fuel
(a)	$CH_4 \longrightarrow \Delta H_c$ 16 g/mol −880 kJ/mol 1 g ? kJ $\Delta H_{c(CH_4)} = \frac{-880}{16} = -55$ kJ
(b)	$\Delta H_{c(C_2H_5OH)} = \frac{-1380}{46} = -30$ kJ
(c)	$\Delta H_{c(C_3H_8)} = \frac{-2200}{44} = -50$ kJ
(d)	$\Delta H_{c(C_7H_{16})} = \frac{-4800}{100} = -48$ kJ

∵ (CH_4) produces the largest amount of thermal energy (55 kJ) when 1 g of it is burnt.

∴ The correct choice is (a)

6

* It is shown from the hydrocarbons in the table that :
  - Each hydrocarbon exceeds the preceded hydrocarbon with (CH_2)
  - Heat of combustion of each hydrocarbon exceeds that of the preceded hydrocarbon by an amount shown in the next table :

Hydrocarbons	$C_3H_8 : C_4H_{10}$	$C_4H_{10} : C_5H_{12}$	$C_5H_{12} : C_6H_{14}$
Difference in the values of heat of combustion	2878 – 2219 = 659 kJ	3535 – 2878 = 657 kJ	4163 – 3535 = 628 kJ

$\therefore$ Average of the elevation of the heat of combustion for each carbon atom $= \frac{659 + 657 + 628}{3} = 648$ kJ

$\because$ Difference between the values of the heat of combustion between the hydrocarbon ($\mathcal{X}$) and the hydrocarbon C_6H_{14} $= 6125 - 4163 = 1962$ kJ

$\therefore$ No. of (CH_2) groups needed to be added to $C_6H_{14} = \frac{1962}{648} \simeq 3$

$\therefore$ The formula of ($\mathcal{X}$) is C_9H_{20}

$\therefore$ The correct choice is (c)

9

$\because$ In the graph : products energy < reactants energy.

$\therefore$ The diagram represents an exothermic reaction.

$\because$ Combustion process is exothermic.

$\therefore$ The choice (a) is excluded.

$\because$ Formation process is either exothermic or endothermic.

$\therefore$ The choice (b) is excluded.

$\because$ Combination (attachment) of the solute molecules with solvent molecules is an exothermic process.

$\therefore$ The choice (c) is excluded.

$\therefore$ The correct choice is (d)

25

① $\frac{1}{2}H_{2(g)} + \frac{1}{2}Cl_{2(g)} \longrightarrow \cancel{HCl_{(g)}}$ $\quad \Delta H^\circ_f = -92.3$ kJ/mol

② $\cancel{HCl_{(g)}} \xrightarrow{\text{water}} H^+_{(aq)} + Cl^-_{(aq)}$ $\quad \Delta H^\circ_{sol} = -75.14$ kJ/mol

By adding the two equations

$\frac{1}{2}H_{2(g)} + \frac{1}{2}Cl_{2(g)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$ $\quad \Delta H^\circ = -167.44$ kJ/mol

$\therefore$ The correct choice is (b)

28

CH_4	$\longrightarrow$	ΔH_c
8 g		– 482.55 kJ
12 + (4 × 1) = 16 g/mol		? kJ/mol

$$\Delta H_c^\circ = \frac{-482.55 \times 16}{8} = -965.1 \text{ kJ/mol}$$

29 (1) Molar mass of CH_4 = 12 + (4 × 1) = 16 g/mol

$$\text{Number of moles of } CH_4 = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{5.76}{16} = 0.36 \text{ mol}$$

$\because \Delta H_c^\circ = \dfrac{-q_p}{n}$

$\therefore q_p = -\Delta H_c^\circ \times n = -(-890) \times 0.36 = +320.4$ kJ

(2) $\because$ Volume of 1 mol of methane gas (at STP) = 22.4 L

$\because$ Volume of methane gas in liters $= \dfrac{500}{1000} = 0.5$ L

$\therefore$ Number of moles (n) $= \dfrac{\text{Volume of gas in liters}}{22.4} = \dfrac{0.5}{22.4} = 0.0223$ mol

$\therefore q_p = -\Delta H_c^\circ \times n = -(-890) \times 0.0223 = +19.8$ kJ

30 (1) $C_3H_8O_{(\ell)} + \frac{9}{2}O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(v)} \quad \Delta H^\circ = -2017$ kJ/mol

(2)

C_3H_8O	is burnt to produce	q_p
60 g		2017 kJ
? g		1×10^4 kJ

$$\text{Mass of propanol} = \frac{60 \times 1 \times 10^4}{2017} = 297.47 \text{ g}$$

31 $q_p = m\,c\,\Delta T = 500 \times 4.18 \times (100 - 20)$

$= +167200$ J $= +167.2$ kJ

$\because \Delta H_c^\circ = \dfrac{-q_p}{n}$

$\therefore n = \dfrac{-q_p}{\Delta H_c^\circ} = \dfrac{-167.2}{-2323.7} = 0.07195$ mol

Molar mass of $C_3H_8 = (3 \times 12) + (8 \times 1) = 44$ g/mol

Mass of propane (C_3H_8) = Molar mass × Number of moles

$= 44 \times 0.07195 = 3.1658$ g

---

32 **(1)** $\because q_p$ absorbed by water = q_p released from burning hexane

«Assuming no heat lost»

$\therefore q_{p(Hexane)} = mc\Delta T = 50 \times 4.18 \times (68 - 22) = 9614$ J

(2) Number of moles of hexane = $\frac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$

$= \frac{0.32}{86} = 3.72 \times 10^{-3}$ mol

$q_{p(kJ)} = \frac{9614}{1000} = 9.614$ kJ

$\therefore \Delta H_c^\circ = \frac{-q_p}{n} = \frac{-9.614}{3.72 \times 10^{-3}} = -2584.4$ kJ/mol

(3) • The possibility of losing a quantity of heat during heating process.

• The possibility of evaporation of a part of hexane after weighing.

• The possibility of incomplete combustion of hexane.

"Any two possibilities or any other correct possibility"

---

33 Molar mass of $C_2H_5OH = (2 \times 12) + (5 \times 1) + 16 + 1 = 46$ g/mol

Number of moles of $C_2H_5OH = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{1.8}{46} = 0.039$ mol

$\because \Delta H_c = \frac{-q_p}{n}$

$\therefore q_{p(Ethanol)} = -\Delta H_c \times n = -(-1364) \times 0.039 = +53.196$ kJ

$q_{p(Water)} = mc\Delta T = 100 \times 4.18 \times (40 - 25) = +6270$ J $= +6.27$ kJ

Lost quantity of heat (not absorbed by water) :

$q_{p(Lost)} = q_{p(Ethanol)} - q_{p(Water)} = (+53.196) - (+6.27) = +46.926$ kJ

Percentage of lost energy = $\frac{46.926}{53.196} \times 100\% = 88.2\%$

34 **(1) 1-** $\Delta H = [2\Delta H^\circ_{f(NH_3)}] - [\Delta H^\circ_{f(N_2)} + 3\Delta H^\circ_{f(H_2)}]$

$-92 = [2\Delta H^\circ_{f(NH_3)}] - [0 + (3 \times 0)]$

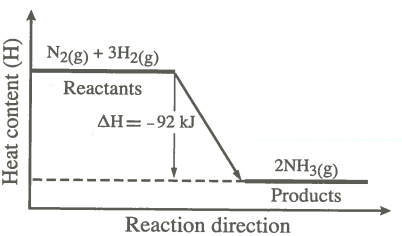
$\Delta H^\circ_{f(NH_3)} = \frac{-92}{2} = -46$ kJ/mol

2-

$2NH_3$	⟶	ΔH
$2[14 + (3 \times 1)] = 34$ g		-92 kJ
30 g		? kJ

$\therefore \Delta H = \frac{30 \times -92}{34} = -81.176$ kJ

(2)



35 $\Delta H^\circ = [\Delta H^\circ_{f(H_2O)}] - [\Delta H^\circ_{f(H_2)} + \frac{1}{2}\Delta H^\circ_{f(O_2)}]$

$-285.8 = \Delta H^\circ_{f(H_2O)} - [0 + (\frac{1}{2} \times 0)]$

$\Delta H^\circ_{f(H_2O)} = -285.8$ kJ/mol

Molar mass of $H_2O = (2 \times 1) + 16 = 18$ g/mol

Number of moles of $H_2O = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{54}{18} = 3$ mol

$\because \Delta H^\circ = \frac{-q_p}{n}$

$\therefore q_p = -\Delta H^\circ \times n = -(-285.8) \times 3 = +857.4$ kJ

36 **(1)**

$$2H_{2(g)} \longrightarrow \Delta H_c$$
$$2 \text{ mol} \qquad -484 \text{ kJ}$$
$$1 \text{ mol} \qquad ? \text{ kJ/mol}$$

$\therefore$ Standard heat of combustion of hydrogen $(\Delta H_c^\circ) = \dfrac{-484 \times 1}{2} = -242$ kJ/mol

(2)

$$2H_2 \longrightarrow \Delta H_c$$
$$2 \times (2 \times 1) = 4 \text{ g} \qquad -484 \text{ kJ}$$
$$1 \text{ g} \qquad ? \text{ kJ}$$

$\therefore$ Heat of combustion of 1g of hydrogen $(\Delta H_c) = \dfrac{-484 \times 1}{4} = -121$ kJ

(3) $\Delta H_c = [2\Delta H^\circ_{f(H_2O)}] - [2\Delta H^\circ_{f(H_2)} + \Delta H^\circ_{f(O_2)}]$

$-484 = 2\Delta H^\circ_{f(H_2O)} - [(2 \times 0) + 0]$

$\Delta H^\circ_{f(H_2O)} = \dfrac{-484}{2} = -242$ kJ/mol

---

37 $\because \Delta H^\circ_{f(CO_2)} = \Delta H^\circ_{c(C)} = -393.5$ kJ/mol

$\because \Delta H^\circ_{f(H_2O)} = \Delta H^\circ_{c(H_2)} = -285.85$ kJ/mol

$\therefore \Delta H_c = [4\Delta H^\circ_{f(CO_2)} + 6\Delta H^\circ_{f(H_2O)}] - [2\Delta H^\circ_{f(C_2H_6)} + 7\Delta H^\circ_{f(O_2)}]$

$\Delta H_c = [(4 \times -393.5) + (6 \times -285.85)] - [(2 \times -140) + (7 \times 0)]$

$\Delta H_c = -3289.1 - (-280) = -3009.1$ kJ

$$2C_2H_6 \longrightarrow \Delta H_c$$
$$2 \text{ mol} \qquad -3009.1 \text{ kJ}$$
$$1 \text{ mol} \qquad ? \text{ kJ/mol}$$

$\therefore$ Change in molar enthalpy of combustion of ethane (ΔH_c°)

$= \dfrac{-3009.1 \times 1}{2} = -1504.55$ kJ/mol

---

38 (1) (2) < (4) < (1) < (3). (2) (4) < (1) < (3) < (2).

(3) (2) < (3) < (1) < (4).

39 Equation (1) / Because the reaction proceeds in the direction of formation of the more stable compound «that has the lower value of heat of formation».

40 **By dividing equation ① ÷ 2**

$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(\ell)}$ $\quad \Delta H_3 = \frac{\Delta H_1}{2} = \frac{-570}{2} = -285$ kJ/mol ③

By adding the equations ② , ③ as follows :

$H_{2(g)} + \frac{1}{2}O_{2(g)} + \cancel{H_2O_{(\ell)}} + \frac{1}{2}O_{2(g)} \longrightarrow \cancel{H_2O_{(\ell)}} + H_2O_{2(\ell)}$

$\Delta H = \Delta H_3 + \Delta H_2 = [(-285 + 33.4)]$ kJ/mol

$H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{2(\ell)}$ $\quad \Delta H^\circ = -251.6$ kJ/mol

41 **By dividing equation ② ÷ 2**

$SO_{3(g)} \longrightarrow SO_{2(g)} + \frac{1}{2}O_{2(g)}$ $\quad \Delta H_3 = \frac{\Delta H_2}{2} = \frac{-296.83}{2} = -148.415$ kJ/mol ③

By adding the equations ① , ③ as follows :

$S_{(s)} + \frac{3}{2}O_{2(g)} + \cancel{SO_{3(g)}} \longrightarrow \cancel{SO_{3(g)}} + SO_{2(g)} + \frac{1}{2}O_{2(g)}$

$\Delta H = \Delta H_1 + \Delta H_3 = [-395.72 + (-148.415)]$ kJ

And by transferring $\frac{1}{2}O_{2(g)}$ from the right side of the equation to the left side with opposite sign :

$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$ $\quad \Delta H = -544.135$ kJ/mol

42 **By multiplying equation ① × 2**

$2C_{(s)} + 2O_{2(g)} \longrightarrow 2CO_{2(g)}$ $\quad \Delta H_4 = 2 \times \Delta H_1 = 2 \times -394 = -788$ kJ ④

By adding the equations ④ , ② and subtracting equation ③ :

$2C_{(s)} + \cancel{2O_{2(g)}} + H_{2(g)} + \cancel{\frac{1}{2}O_{2(g)}} - C_2H_{2(g)} - \cancel{\frac{5}{2}O_{2(g)}} \longrightarrow$

$\cancel{2CO_{2(g)}} + \cancel{H_2O_{(v)}} - \cancel{2CO_{2(g)}} - \cancel{H_2O_{(v)}}$

$\Delta H^\circ = \Delta H_4 + \Delta H_2 - \Delta H_3 = [-788 + (-286) - (-1300)]$ kJ/mol

And by transferring $C_2H_{2(g)}$ from the left side of the equation to the right side with opposite sign :

$2C_{(s)} + H_{2(g)} \longrightarrow C_2H_{2(g)}$ $\quad \Delta H^\circ = +226$ kJ/mol

Answers of the new types of questions

1 (a) , (e) 2 (d) , (e) 3 (b) , (d) 4 (c) , (d) 5 (d) , (e)

Answers of the general exercises on Unit 4

1 (b)	2 (d)	3 (c)	4 (a)	5 (a)
6 (c)	7 (a)	8 (d)	9 (c)	10 (c)
11 (b)	12 (b)	13 (a)	14 (d)	15 (a)
16 (d)	17 (d)	18 (b)	19 (d)	20 (d)
21 (a)	22 (c)	23 (b)	24 (b)	

25 $q_p = 100 \text{ cal} = 100 \times 4.18 = 418 \text{ J}$

$$\Delta T = \frac{q_p}{mc} = \frac{418}{100 \times 0.24} = 17.4^\circ C$$

26 $\Delta T = T_2 - T_1 = 55.1 - 25.2 = 29.9^\circ C$

$\because q_p = mc\Delta T$

$$\therefore c = \frac{q_p}{m\Delta T} = \frac{133}{5 \times 29.9} = 0.889 \text{ J/g.}^\circ C$$

$\therefore$ The substance is X

27 $HBr_{(g)} \longrightarrow \frac{1}{2}Br_{2(\ell)} + \frac{1}{2}H_{2(g)} \qquad \Delta H^\circ = +36 \text{ kJ/mol}$

28 ΔH = Energy absorbed during breaking reactants bonds (with positive sign) + Energy released during the formation of products bonds (with negative sign)

$\Delta H = [4(N-H) + (N-N) + (O=O)] - [2 \times 2(O-H) + (N \equiv N)]$

$-577 = (4 \times 391) + (N-N) + 495 - (4 \times 463) - 941$

$-577 = (N-N) - 734$

$\therefore$ (N – N) average bond energy = 157 kJ/mol

29 ΔH = Energy absorbed during breaking reactants bonds (with positive sign) + Energy released during the formation of products bonds (with negative sign)

$\therefore \Delta H = 2(X - Y) - [(X - X) + \frac{1}{2}(Y = Y)]$

$= (2 \times 467) - 432 - (\frac{1}{2} \times 498) = +253$ kJ/mol

$\because$ ΔH value has positive sign.

$\therefore$ The reaction is endothermic.

---

30 **(1)** $\Delta H = [(H - H) + (Cl - Cl)] - [2(H - Cl)]$

$= 432 + 240 - (2 \times 430) = -188$ kJ

(2) The reaction is exothermic / Because the amount of energy released during the formation of the products bonds is larger than the amount of energy absorbed during breaking the reactants bonds.

---

31 $2Ca_{(s)} + O_{2(g)} \longrightarrow 2CaO_{(s)}$ $\Delta H = -1270.2$ kJ

---

32 **(1)** ΔH = The sum of the heat of formation of products − The sum of the heat of formation of reactants

$\Delta H = [2\Delta H^{\circ}_{f(CO_2)} + 3\Delta H^{\circ}_{f(H_2O)}] - [\Delta H^{\circ}_{f(C_2H_6)} + \frac{7}{2} \Delta H^{\circ}_{f(O_2)}]$

$\therefore \Delta H = [(2 \times -393.5) + (3 \times -286)] - [(-84.67) + (\frac{7}{2} \times 0)]$

$= -1560.33$ kJ/mol

(2) The reaction is exothermic / Because the sum of the heat of formation of the products is lower than the sum of the heat of formation of the reactants.

---

33 **(1)** $C_3H_8 + 5O_2 \longrightarrow 3CO_{2(g)} + 4H_2O_{(v)}$ $\Delta H^{\circ}_c = -2220$ kJ/mol

(2) Molar mass of propane $C_3H_8 = (3 \times 12) + (8 \times 1) = 44$ g/mol

Number of moles of propane $= \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{0.44}{44} = 0.01$ mol

$\because \Delta H_c^\circ = \frac{-q_p}{n}$

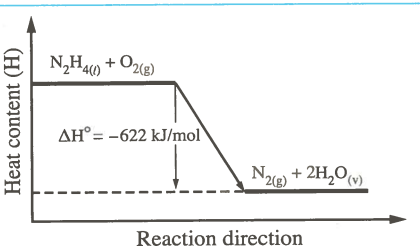
$\therefore q_p = -\Delta H_c^\circ \times n = -(-2220) \times 0.01 = 22.2$ kJ

34 $\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \longrightarrow NH_{3(g)}$ $\Delta H_f^\circ = -46$ kJ/mol

Answers of the exam model about Unit 4

1 (c)	2 (c)	3 (c)	4 (c)	5 (d)
6 (c)	7 (c)	8 (d)	9 (d)	10 (a)

11



12 $Z \longrightarrow X$ $\Delta H = -80$ kJ/mol

$X \longrightarrow W$ $\Delta H = +130$ kJ/mol

By addition

$Z + \cancel{X} \longrightarrow \cancel{X} + W$ $\Delta H = -80 + 130 = +50$ kJ/mol

$Z \longrightarrow W$ $\Delta H = +50$ kJ/mol

13 ΔH_3 value / Hydration energy.

14 * **Importance of the gas :** The substance which is meant to measure its heat of combustion is burnt in excess of it.

* **The liquid :** Water.

15 **(1)** Ammonium nitrate NH_4NO_3

(2) Number of moles (n) $= \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{0.4}{40} = 0.01$ mol

$\because \Delta H = \frac{-q_p}{n}$

$\therefore q_p = -\Delta H \times n = -(-51) \times 0.01 = +0.51$ kJ

16 $\because \Delta H^\circ_{f(CO_2)} = \Delta H^\circ_{c(C)} = -393.5$ kJ/mol

$\therefore$ The equation which represents the heat of formation of carbon dioxide from its elements is :

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\qquad \Delta H^\circ_f = -393.5$ kJ/mol

$C_2H_{2(g)} + \frac{5}{2}O_{2(g)} \longrightarrow 2CO_{2(g)} + H_2O_{(\ell)}$ $\qquad \Delta H^\circ_c = -1300$ kJ/mol

$\Delta H^\circ_{f(H_2O)} = \Delta H^\circ_{c(H_2)} = -285.85$ kJ/mol

$\Delta H^\circ_c = [2\Delta H^\circ_{f(CO_2)} + \Delta H^\circ_{f(H_2O)}] - [\Delta H^\circ_{f(C_2H_2)} + \frac{5}{2}\Delta H^\circ_{f(O_2)}]$

$-1300 = [(2 \times -393.5) + (-285.85)] - [\Delta H^\circ_{f(C_2H_2)} + (\frac{5}{2} \times 0)]$

$-1300 = -1072.85 - \Delta H^\circ_{f(C_2H_2)}$

$\therefore \Delta H^\circ_{f(C_2H_2)} = 1300 - 1072.85 = +227.15$ kJ/mol

$\therefore$ The equation which represents the heat of formation of acetylene from its elements is :

$2C_{(s)} + H_{2(g)} \longrightarrow C_2H_{2(g)}$ $\qquad \Delta H^\circ_f = +227.15$ kJ/mol

17 * **By multiplying equation (2) × 2 then reversing the reaction direction :**

$4NH_{3(g)} \longrightarrow 2N_{2(g)} + 6H_{2(g)}$ $\qquad \Delta H_4 = 2 \times (+91.8) = +183.6$ kJ (4)

* **By multiplying equation (1) × 2 :**

$2N_{2(g)} + 4O_{2(g)} \longrightarrow 4NO_{2(g)}$ $\qquad \Delta H_5 = 2 \times (-180.5) = -361$ kJ (5)

* **By multiplying equation (3) × 3 :**

$6H_{2(g)} + 3O_{2(g)} \longrightarrow 6H_2O_{(v)}$ $\quad \Delta H_6 = 3 \times (-483.6) = -1450.8$ kJ (6)

* **By adding the equations (4) , (5) and (6) :**

$4NH_{3(g)} + \cancel{2N_{2(g)}} + 4O_{2(g)} + \cancel{6H_{2(g)}} + 3O_{2(g)} \longrightarrow$

$\cancel{2N_{2(g)}} + \cancel{6H_{2(g)}} + 4NO_{2(g)} + 6H_2O_{(v)}$

$\Delta H = \Delta H_4 + \Delta H_5 + \Delta H_6 = +183.6 + (-361) + (-1450.8) = -1628.2$ kJ

$4NH_{3(g)} + 7O_{2(g)} \longrightarrow 4NO_{2(g)} + 6H_2O_{(v)}$ $\quad \Delta H = -1628.2$ kJ

Answers of Unit 5 Chapter One lesson 1

1 (b)	2 (c)	3 (d)	4 (a)	5 (c)
6 (d)	7 (c)	8 (c)	9 (d)	10 (b)
11 (a)	12 (d)	13 (c)	14 (c)	15 (c)

Ideas of answering the questions marked by the mark ○

Question number	Idea of answering
4	It is shown in the table that the mass of (X) is larger than that of (Y). ∵ Mass of the neutron equals approximately that of the proton. ∴ The choices (b) and (c) are excluded. ∵ Mass of the proton is larger than that of the electron. ∴ The choice (d) is excluded. ∴ The correct choice is (a)
14	∵ Figure (a) shows that the element has only one isotope. ∴ Figure (a) is excluded. * Atomic mass of copper should be calculated in each figure and the correct choice is that whose atomic mass equals 63.62 u

In figure (b) :

Contribution of $^{62}Cu = 62 \times \frac{17}{100} = 10.54$ u

Contribution of $^{63}Cu = 63 \times \frac{33}{100} = 20.79$ u

Contribution of $^{65}Cu = 65 \times \frac{50}{100} = 32.5$ u

$\therefore$ Atomic mass of Cu = 10.54 + 20.79 + 32.5 = 63.83 u

$\therefore$ The choice (b) is excluded.

In figure (c) :

Contribution of $^{63}Cu = 63 \times \frac{69}{100} = 43.47$ u

Contribution of $^{65}Cu = 65 \times \frac{31}{100} = 20.15$ u

$\therefore$ Atomic mass of copper Cu = 43.47 + 20.15 = 63.62 u

$\therefore$ The correct choice is (c)

15

$\because$ No. of neutrons in the nucleus of Uuq = 289 – 114 = 175 neutrons.

No. of neutrons in the nucleus of Uuh = 292 – 116 = 176 neutrons.

$\therefore$ Nucleus of Uuh has one more neutron than that of Uuq

$\therefore$ The choice (a) is excluded.

$\because$ Uuq^{2-} ion contains 116 electrons which is the same number of electrons found in Uuh atom.

$\therefore$ The choice (b) is excluded.

$\because$ Uuh^{+} ion contains 115 electrons which does not equal the number of electrons found in Uuq atom.

$\therefore$ The correct choice is (c)

16 Similarity of the isotopes of the same element in their chemical properties.

17 (1) $^{65}_{29}X_{36}$ (2) $^{45}_{20}Y_{25}$ (3) $^{84}_{36}Z_{48}$

18 **(1)** Protium / Proton. **(2)** 1 / Proton.

19 **(1)** 11 protons , 11 electrons.

(2) Number of nucleons = Number of protons + Number of neutrons

= 11 + 13 = 24 nucleons

(3) They all have the same chemical properties.

20 **(1)** That means astatine element has different atoms which are similar in their atomic number and different in their mass number.

(2) Atomic number = Number of protons = Number of electrons = 85

(3) Number of neutrons = Mass number – Atomic number

= 210 – 85 = 125 neutrons

(4) $^{210}_{85}At_{125}$

21 **(1)** 20

(2) Because they both have the same number of protons (atomic number) with the difference of the number of neutrons, hence their mass numbers are different.

22 Contribution of gallium – 69 in the atomic mass = $68.93 \times \frac{60.11}{100} = 41.43$ u

Contribution of gallium – 71 in the atomic mass = $70.92 \times \frac{39.89}{100} = 28.29$ u

Atomic mass of gallium Ga = 41.43 + 28.29 = 69.72 u

23 Contribution of magnesium – 24 in the atomic mass = $23.985 \times \frac{78.7}{100}$

= 18.876 u

Contribution of magnesium – 25 in the atomic mass = $24.986 \times \frac{10.13}{100}$

= 2.531 u

Contribution of magnesium – 26 in the atomic mass = $25.983 \times \frac{11.17}{100}$

= 2.902 u

Atomic mass of magnesium element Mg = 18.876 + 2.531 + 2.902

= 24.309 u

24 Contribution of the isotope ^{74}X in the atomic mass $= 74 \times \frac{0.89}{100}$

$= 0.6586$ u

Contribution of the isotope ^{76}X in the atomic mass $= 76 \times \frac{9.37}{100}$

$= 7.1212$ u

Contribution of the isotope ^{77}X in the atomic mass $= 77 \times \frac{7.63}{100}$

$= 5.8751$ u

Contribution of the isotope ^{78}X in the atomic mass $= 78 \times \frac{23.77}{100}$

$= 18.5406$ u

Contribution of the isotope ^{80}X in the atomic mass $= 80 \times \frac{49.61}{100}$

$= 39.688$ u

Contribution of the isotope ^{82}X in the atomic mass $= 82 \times \frac{8.73}{100}$

$= 7.1586$ u

Atomic mass of the element X $= 0.6586 + 7.1212 + 5.8751 + 18.5406 + 39.688 + 7.1586$

$= 79.0421$ u

$E\ (J) = m\ (kg) \times c^2$ **$E\ (MeV) = m\ (u) \times 931$**

25 **(1)** $m\ (kg) = \frac{0.2}{1000} = 2 \times 10^{-4}$ kg

$E\ (J) = 2 \times 10^{-4} \times (3 \times 10^8)^2 = 1.8 \times 10^{13}$ J

(2) $m\ (u) = \frac{0.2}{1.66 \times 10^{-24}} = 1.2 \times 10^{23}$ u

$E\ (MeV) = 1.2 \times 10^{23} \times 931 = 1.12 \times 10^{26}$ MeV

26 $E = 0.00234 \times 931 = 2.179$ MeV

27 **(1)** $m = 10 \times \frac{50}{100} = 5\ g$

$E = \frac{5}{1000} \times (3 \times 10^8)^2 = 4.5 \times 10^{14}\ J$

(2) $m\ (u) = \frac{5}{1.66 \times 10^{-24}} = 3.01 \times 10^{24}\ u$

$E = 3.01 \times 10^{24} \times 931 = 2.80231 \times 10^{27}\ MeV$

---

28 $m\ (u) = \frac{E}{931} = \frac{190}{931} = 0.2\ u$

$m\ (kg) = 0.2 \times 1.66 \times 10^{-27} = 3.32 \times 10^{-28}\ kg$

---

29 **(1)** $m\ (u) = \frac{E}{931} = \frac{6.8419}{931} = 7.35 \times 10^{-3}\ u$

(2) $m\ (g) = 7.35 \times 10^{-3} \times 1.66 \times 10^{-24} = 1.22 \times 10^{-26}\ g$

Answers of the new types of questions

1 (a) , (b)

2 (d) , (e)

3 • Atomic mass unit.

• Joule.

Answers of Unit 5 Chapter One lesson 2

1 (c)	2 (a)	3 (d)	4 (a)	5 (b)
6 (c)	7 (b)	8 (b)	9 (c)	10 (b)
11 (b)	12 (b)	13 (a)	14 (c)	
15 1– (a)	2– (c)	16 1– (b)	2– (a)	17 (c)
18 (b)	19 (a)			

Ideas of answering the questions marked by the mark ○

Question number	Idea of answering
1	It is clear in the figure that : * The attraction force (W) does not depend on the charge of the nucleons, where it is found between (X) and (X) , and between (Y) and (Y), as well as between (X) and (Y). ∴ (W) is a strong nuclear force. ∴ The choices (b) and (d) are excluded. * There is a repulsion force between (X) and (X) which is an electrostatic force found among the protons only. ∴ (X) is the proton and (Y) is the neutron. ∴ The correct choice is (c)
16	1– ∵ This element undergoes a positron emission reaction. ∴ The element lies at the right side of the belt of stability. ∴ The choices (c) and (d) are excluded. ∵ No. of protons = 20 protons , No. of neutrons = 15 neutrons. ∴ $\frac{N}{Z} = \frac{15}{20} = 0.75$ Referring to the figure, it is noticed that the element lies down the belt of stability. ∴ The correct choice is (b) 2– No. of protons = 30 protons , No. of neutrons = 40 neutrons. Referring to the figure, the element lies at the left side of the belt of stability. ∴ The nucleus of $^{70}_{30}Zn$ emits a beta particle. ∴ The correct choice is (a)

17

∵ The nucleus of this element lies above the left side of the belt of stability.

∴ No. of the neutrons in it is larger than the stability level ($\frac{N}{Z}$ is large).

∴ To reduce $\frac{N}{Z}$ ratio (neutrons : protons), a beta particle is emitted from the nucleus to transform one of the neutrons into a proton.

∴ The correct choice is (c)

* **Nuclear binding energy (BE) = Mass defect × 931**
* **Theoretical mass =**
  (Number of protons × Proton mass) + (Number of neutrons × Neutron mass)
* **Mass defect = Theoretical mass – Actual mass**
* **Nuclear binding energy per nucleon** $\left(\frac{BE}{A}\right) = \frac{\text{Nuclear binding energy (BE)}}{\text{Number of nucleons (Mass number) (A)}}$

20 Theoretical mass = (1 × 1.00728) + (1 × 1.00866) = 2.01594 u

Mass defect = 2.01594 – 2.014102 = 1.838×10^{-3} u

Nuclear binding energy (BE) = $1.838 \times 10^{-3} \times 931 = 1.71$ MeV

21 Number of neutrons = 6 – 3 = 3 neutrons

Theoretical mass = (3 × 1.00728) + (3 × 1.00866) = 6.04782 u

Mass defect = 6.04782 – 6.015 = 0.03282 u

Nuclear binding energy = 0.03282 × 931 = 30.56 MeV

22 Nuclear binding energy (BE) = 0.5 × 931 = 465.5 MeV

23

	Nitrogen isotope $^{14}_{7}N$	Nitrogen isotope $^{15}_{7}N$
Nuclear binding energy (BE)	$= 0.105 \times 931$ $= 97.755$ MeV	$= 0.115 \times 931$ $= 107.065$ MeV
Nuclear binding energy per nucleon $\left(\frac{BE}{A}\right)$	$= \frac{97.755}{14} = 6.9825$ MeV	$= \frac{107.065}{15} = 7.1377$ MeV

$\therefore$ Isotope $^{15}_{7}N$ is more stable than the isotope $^{14}_{7}N$ / Because the amount of binding energy per nucleon $\left(\frac{BE}{A}\right)$ is higher in it.

$$\textbf{Mass defect (transformed mass)} = \frac{\textbf{Nuclear binding energy (BE)}}{\textbf{931}}$$

24 Nuclear binding energy (BE)

= Nuclear binding energy per nucleon × Number of nucleons

$= 7.070945 \times 4 = 28.28378$ MeV

Transformed mass $= \frac{28.28378}{931} = 0.03038$ u

Actual mass = Theoretical mass – Mass defect

25 Nuclear binding energy $= 7.42007 \times 12 = 89.04$ MeV

Mass defect $= \frac{89.04}{931} = 0.0956$ u

Theoretical mass $= (6 \times 1.00728) + (6 \times 1.00866) = 12.0956$ u

Actual mass $= 12.0956 - 0.0956 = 12$ u

26 Mass defect $= \frac{192.717}{931} = 0.207$ u

Theoretical mass $= (12 \times 1.00728) + (12 \times 1.00866) = 24.19128$ u

Mass of the nucleus of magnesium atom after combining its constituents (actual mass) $= 24.19128 - 0.207 = 23.98428$ u

Theoretical mass = Actual mass + Mass defect

27 Mass defect = $\frac{90.8656}{931}$ = 0.0976 u

Theoretical mass = 13.0057 + 0.0976 = 13.1033 u

28 Mass defect = $\frac{521.788}{931}$ = 0.5605 u

Mass of protons and neutrons (Theoretical mass) = 60.93244 + 0.5605

= 61.49294 u

29 (1) Mass defect = $\frac{824.3074}{931}$ = 0.8854 u

Theoretical mass = 95.889 + 0.8854 = 96.7744 u

(2) Number of neutrons = $\frac{\text{Mass of neutrons}}{\text{Mass of neutron}} = \frac{55.4763}{1.00866}$ = 55 neutrons

Atomic number = Number of protons = Mass number – Number of neutrons

= 96 – 55 = 41

Mass number (A) = $\frac{\text{Nuclear binding energy (BE)}}{\text{Nuclear binding energy per nucleon } \left(\frac{BE}{A}\right)}$

30 Mass number (A) = $\frac{342}{8.55}$ = 40

31 Mass number (A) = $\frac{186.03}{6.89}$ = 27

Atomic number (Z) = 2 + 8 + 3 = 13

Number of neutrons (N) = Mass number (A) – Atomic number (Z)

= 27 – 13 = 14 neutrons

32 Nucleus of the isotope $^{241}_{95}Am$ / Because number of nucleons in it is higher than the stability level.

33 (1) $^{15}_{8}O \xrightarrow{\beta^+} {}^{15}_{7}N$ ∴ The produced element is nitrogen – 15

(2) $^{14}_{6}C \xrightarrow{\beta^-} {}^{14}_{7}N$ ∴ The produced element is nitrogen – 14

34 (1) The right side of the belt of stability.

(2)

	β^+	β^-
The similarity	Each of them is emitted from a nucleus of an unstable element atom to reach the stability state	
The difference	Each of them has a different type of charge	
	Positive nucleus electron	Negative nucleus electron

35 (1) Number of neutrons. (2) Equals 1

(3) $^{107}_{47}Ag$ /

- **First reason :** Number of neutrons in the graphical figure refers to 60 and not 85
- **Second reason :** The element is located in the belt of stability zone, that means $\frac{N}{Z}$ ratio in it is 1.28 and not 1.8

36 (1) **(A) :** Neutron (n) , **(B) :** Proton (p).

* $Q_n = \frac{2}{3} + (-\frac{1}{3}) + (-\frac{1}{3}) = 0$
* $Q_p = -\frac{1}{3} + \frac{2}{3} + \frac{2}{3} = +1\ e$

(2) Negative charge.

37 Number of protons = Atomic number = 8 protons

Number of neutrons = Mass number – Atomic number

= 17 – 8 = 9 neutrons

Number of up quarks in $^{17}_{8}O$

= No. of up quarks of the protons + No. of up quarks of the neutrons

= (8 × 2) + (9 × 1) = 25 up quarks (u).

Answers of the new types of questions

1 (a) , (c) 2 (b) , (e) 3 (c) , (e)

4 • (1) refers to p • (2) refers to u

Answers of Unit 5 Chapter Two lesson 1

1 (d)	2 (d)	3 (a)	4 (d)	5 (b)
6 (b)	7 (c)	8 (d)	9 (c)	10 (c)
11 (c)	12 (d)	13 (c)	14 (c)	15 (d)
16 (a)	17 (d)	18 (c)	19 (d)	20 (d)
21 (b)	22 (c)	23 (b)	24 (d)	25 (b)
26 (c)	27 (a)	28 (c)		

Ideas of answering the questions marked by the mark

Question number	Idea of answering
17	∵ The ability of alpha radiation to penetrate the different media is weak (cannot penetrate a paper). ∴ The choices (a) and (b) are excluded. ∵ Gamma radiation is not affected by the magnetic field, so it penetrates the paper in a straight line, and cannot be recieved by Geiger counter. ∴ The choice (c) is excluded. ∴ The correct choice is (d)
27	∵ Number of radioactive nuclei N decreases by the time t. ∴ The choices (c) and (d) are excluded. ∵ Number of radioactive nuclei N decreases to half its value after each half life time, **i.e.** It does not decrease by constant values and does not reach zero. ∴ The choice (b) is excluded. ∴ The correct choice is (a)

29 The arrows (2) , (3) / Due to the formation of a new element in each of them, its atomic number is less by 2, and its mass number is less by 4 than the parent nucleus.

30 (1) Number of neutrons = Mass number – Number of protons
= 210 – 84 = 126 neutrons

(2)

	$^{210}_{82}Pb$	$\longrightarrow$	$^{210}_{83}Bi$
Number of protons :	82		83
Number of neutrons :	128		127

∴ **The change :**

* Number of protons increased by 1
* Number of neutrons decreased by 1

* **Type of reaction :** Natural transmutation by emitting a beta particle.

$$^{210}_{82}Pb \longrightarrow {}^{210}_{83}Bi + {}^{0}_{-1}e$$

31 (1) $^{222}_{86}X$ (2) $^{144}_{60}X$ (3) $^{95}_{37}X$ (4) $^{233}_{91}X$ (5) $^{238}_{92}X$

32 (1) $^{232}_{90}Th \longrightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$ (2) $^{228}_{88}Ra \longrightarrow {}^{228}_{89}Ac + {}^{0}_{-1}e$

(3) $^{228}_{89}Ac \longrightarrow {}^{228}_{90}Th + {}^{0}_{-1}e$ (4) $^{228}_{90}Th \longrightarrow {}^{224}_{88}Ra + {}^{4}_{2}He$

33 $^{226}_{88}X \longrightarrow {}^{A}_{Z}Y + 5\,{}^{4}_{2}He + 4\,{}^{0}_{-1}e$

$226 = A + (5 \times 4) + (4 \times 0)$

$226 = A + 20$

$A = 226 - 20 = 206$

∴ Mass number decreases by 20

$88 = Z + (5 \times 2) + (4 \times -1)$

$88 = Z + 10 - 4$

$Z = 88 - 6 = 82$

∴ Atomic number decreases by 6

34 $^{238}_{92}U \longrightarrow {}^{206}_{82}Pb + X\,{}^{4}_{2}He + Y\,{}^{0}_{-1}e$

$238 = 206 + (X \times 4) + (Y \times 0)$

$238 = 206 + 4X \qquad \therefore X = 8$

$\therefore$ Number of emitted alpha particles = 8 particles

$92 = 82 + (X \times 2) + (Y \times -1)$

$92 = 82 + (8 \times 2) - Y \qquad \therefore Y = 6$

$\therefore$ Number of emitted beta particles = 6 particles

---

35 $^{A}_{Z}X \longrightarrow {}^{23}_{11}Na + {}^{0}_{-1}e$

$A = 23 + 0 = 23 \qquad Z = 11 + (-1) = 10$

$\therefore$ Number of nucleons = 23 nucleons

Number of neutrons = Mass number – Atomic number = 23 – 10 = 13 neutrons

---

36 $^{A}_{Z}X \longrightarrow {}^{A_1}_{Z_1}Y + 2\,{}^{4}_{2}He + 4\,{}^{0}_{-1}e$

$\because A = A_1 + (2 \times 4) + (4 \times 0) \qquad \therefore A = A_1 + 8$

$\because Z = Z_1 + 4 - 4 \qquad \therefore Z = Z_1$

No elemental transmutation happened / Because the produced isotope of the element $^{A}_{Z}X$ is similar to it in the atomic number but it is different in the mass number.

---

37 $^{234}_{90}A$, $^{234}_{91}B$, $^{230}_{89}C$, $^{230}_{92}D$

* **Element D** and uranium $^{238}_{92}U$ are isotopes.

$$\textbf{Half-life } (t_{\frac{1}{2}}) = \frac{\textbf{Total decay time (t)}}{\textbf{Number of periods (D)}}$$

38 Remained percentage = 100% – 87.5% = 12.5%

$100\% \xrightarrow[(1)]{t_{\frac{1}{2}}} 50\% \xrightarrow[(2)]{t_{\frac{1}{2}}} 25\% \xrightarrow[(3)]{t_{\frac{1}{2}}} 12.5\%$

$\because D = 3 \qquad \therefore t_{\frac{1}{2}} = \frac{t}{D} = \frac{2}{3} = 0.67$ month

$$\text{Number of periods (D)} = \frac{\text{Total decay time (t)}}{\text{Half-life } (t_{\frac{1}{2}})}$$

39 $D = \frac{t}{t_{\frac{1}{2}}} = \frac{10}{5} = 2$

$1\ g \xrightarrow[(1)]{t_{\frac{1}{2}}} \frac{1}{2}\ g \xrightarrow[(2)]{t_{\frac{1}{2}}} \frac{1}{4} g$

No / Because $\frac{1}{4}$ of its original mass remains after passing 10 days.

40 **(1)** Emitting beta particle β^- / Due to the formation of a new element whose atomic number is higher by 1, with remaining the mass number unchanged.

(2) It is shown in the figure that 4 nuclei of magnesium –28 remained from 16 nuclei.

16 nuclei $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 8 nuclei $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 4 nuclei

$\therefore$ Number of half-life times = 2 times.

41 **(1)** 2 days **(2)** 20 g

(3) $\because$ Remaining mass after 6 days = 10 g

$\therefore$ Decayed mass = 80 – 10 = 70 g

42 It is shown in the graphical figure that half-life of this radioactive source is two days.

$D = \frac{t}{t_{\frac{1}{2}}} = \frac{8}{2} = 4$

$\therefore$ 4000 decay/s $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 2000 decay/s $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1000 decay/s $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 500 decay/s $\xrightarrow[(4)]{t_{\frac{1}{2}}}$ 250 decay/s

$\therefore$ Rate of decaying in 8^{th} day = 250 decay/s

Total decay time (t) = Half-life ($t_{\frac{1}{2}}$) × Number of periods (D)

43 Remained mass = $32 \times \frac{1}{4} = 8$ g

$32\text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} 16\text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} 8\text{ g}$

$t = t_{\frac{1}{2}} \times D = 3 \times 2 = 6$ years

---

44 15.3 decay/min $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 7.65 decay/min

$t = t_{\frac{1}{2}} \times D = 5700 \times 1 = 5700$ years

∴ The date of the death of this pharaoh is 5700 years ago.

---

45 $1\text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} \frac{1}{2}\text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} \frac{1}{4}\text{ g}$

$X_1 = t_{\frac{1}{2}} \times D_1 = 20 \times 1 = 20$ days

$X_2 = t_{\frac{1}{2}} \times D_2 = 20 \times 2 = 40$ days

---

46 $t = 1 \times 12 = 12$ months

$D = \frac{t}{t_{\frac{1}{2}}} = \frac{12}{4} = 3$

$64\text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} 32\text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} 16\text{ g} \xrightarrow[(3)]{t_{\frac{1}{2}}} 8\text{ g}$

∴ Remained mass = 8 g

---

47 **(1)** $1\text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} 0.5\text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} 0.25\text{ g}$

$t_{\frac{1}{2}} = \frac{t}{D} = \frac{28}{2} = 14$ h

(2) $D = \frac{t}{t_{\frac{1}{2}}} = \frac{28}{14} = 2$

$0.25\text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} 0.125\text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} 0.0625\text{ g}$

∴ Remained phosphorus mass = 0.0625 g

48 **(1)** ∵ $\frac{7}{8}$ of the number of atoms disintegrated.

∴ Number of remained atoms = $1 - \frac{7}{8} = \frac{1}{8}$ of the original mass.

Number of remained atoms = $\frac{1}{8} \times 4.8 \times 10^{12} = 0.6 \times 10^{12}$ atoms

(2) 4.8×10^{12} atoms $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 2.4×10^{12} atoms $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1.2×10^{12} atoms $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 0.6×10^{12} atoms

∵ D = 3 ∴ $t_{\frac{1}{2}} = \frac{t}{D} = \frac{9}{3} = 3$ months

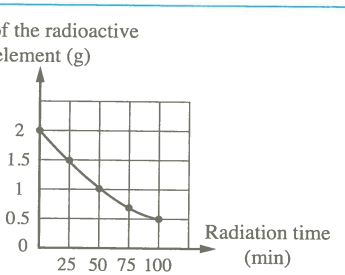
49 $D = \frac{t}{t_{\frac{1}{2}}} = \frac{72.3}{24.1} = 3$

∵ Number of atoms of 1 mol of any element at the standard conditions $= 6.02 \times 10^{23}$ atoms

6.02×10^{23} atoms $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 3.01×10^{23} atoms $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1.505×10^{23} atoms $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 0.7525×10^{23} atoms

∴ Number of remained atoms = 0.7525×10^{23} atoms

50 **(1)**



(2) 50 min

(3) $D = \frac{t}{t_{\frac{1}{2}}} = \frac{150}{50} = 3$

2 g $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 1 g $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 0.5 g $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 0.25 g

∴ Remained mass = 0.25 g

51 $D = \frac{t}{t_{\frac{1}{2}}} = \frac{4}{1} = 4$

4.8×10^{12} atoms $\xrightarrow[(4)]{t_{\frac{1}{2}}}$ 9.6×10^{12} atoms $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 19.2×10^{12} atoms

$\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 38.4×10^{12} atoms $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 76.8×10^{12} atoms

∴ Number of nuclei of atoms in this sample before decaying

$= 76.8 \times 10^{12}$ atoms

Answers of the new types of questions

1 (b) , (d) 2 (a) , (d) 3 (d) , (e)

4 • (1) represents : Negative pole.

• (2) represents : Beta particle.

Answers of Unit 5 Chapter Two lesson 2

1 (d)	2 (d)	3 (d)	4 (b)	5 (a)
6 (c)	7 (c)	8 (a)	9 (a)	10 (c)
11 (d)	12 (d)	13 (b)	14 (a)	15 (d)
16 (b)				

Ideas of answering the questions marked by the mark ○

Question number	Idea of answering
12	∵ Energy produced from the chemical reactions is very limited compared to that produced from the nuclear reactions. ∴ The choices (a) and (c) are excluded. ∵ Energy produced from the nuclear fusion reaction is greater than that produced from the nuclear fission reaction. ∴ The choice (b) is excluded. ∴ The correct choice is (d)

13

$\because$ The nucleus which produces spontaneous emissions is unstable.

$\therefore$ ^{3}H isotope is unstable.

$\therefore$ The choices (c) and (d) are excluded.

$\because$ All hydrogen isotopes are light nuclei which can fuse together to form a heavier nucleus.

$\therefore$ The correct choice is (b)

17 **(1)** * **In chemical reactions :** The element loses electrons from the outermost energy level of the atom.

* **In nuclear reactions :** The element loses nucleus electrons (beta particles) from the nucleus of the atom.

(2) * **In chemical reactions :** The element does not transform to another element.

* **In nuclear reactions :** The element transforms to its isotope or to another element.

18 **(1)** $^{9}_{4}X$ **(2)** $^{28}_{13}X$

19 **(1)** $^{1}_{1}H$ **(2)** $3\,^{4}_{2}He$

20 $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{90}_{38}Sr + {}^{144}_{58}Ce + 2\,{}^{1}_{0}n + 4\,{}^{0}_{-1}e$

21 **(1)** That the sum of the atomic numbers of the reactants equals the sum of the atomic numbers of the products.

(2) That the sum of the mass numbers of the reactants equals the sum of the mass numbers of the products.

(3) • $92 + 0 = 56 + Z + (X \times 0)$ $\therefore Z = 36$

• $235 + 1 = 141 + 92 + (X \times 1)$ $\therefore X = 3$

22 Because the produced neutrons do not have the adequate amount of energy to start a chain (serial) reaction.

23 **(1)** Chain (serial) fission.

(2) Controlling the rate of fission chain reactions by absorbing the neutrons produced from them.

24 **(1)** $_{1}^{2}H + _{1}^{3}H \longrightarrow {}_{2}^{4}He + {}_{0}^{1}n$

(2) **1–** Mass defect = Mass of the fused nuclei – Mass of the produced nucleus

$= 5.031 - 5.011 = 0.02$ u

$E\ (MeV) = 0.02 \times 931 = 18.62$ MeV

2– $E\ (J) = 18.62 \times 1.6 \times 10^{-13} = 2.9792 \times 10^{-12}$ J

25 By adding all the given equations, the following final equation is obtained :

$$4\,{}_{1}^{1}H \longrightarrow {}_{2}^{4}He + 2\,{}_{+1}^{0}e + 4\gamma$$

26 **(1)** **1–** The two isotopes $_{6}^{9}C$, $_{6}^{17}C$ / Because sensitive films are affected by the radiations emitted from the unstable isotopes.

2– $_{6}^{9}C$ / Because the number of protons in it is higher than the stability level « $\frac{N}{Z}$ ratio is small».

3– $_{6}^{17}C$ / Because the number of neutrons in it is higher than the stability level « $\frac{N}{Z}$ ratio is large».

(2) The product is the same in the two cases / Due to the similarity of the isotopes of the same element in their chemical properties.

27 **(1)** To preserve it from spoiling and prolong its storage time.

(2) That the container contains radioactive substances and must be handled with caution.

28 **(1)** By using the suitable insecticides produced from some chemical reactions.

(2) By sterilization of the males of the insects by using gamma radiations.

29 **(1) :** X-ray , γ–ray or neutron.

(2) : Beta radiation. **(3) :** Alpha radiation.

Answers of the new types of questions

1 (b) , (c) **2** (a) , (d) **3** (c) , (d)

4
- **(1) represents :** Barium –141
- **(2) represents :** Krypton –92

Answers of the general exercises on Unit 5

1 (a) **2** (d) **3** (c) **4** (c) **5** (d)

6 (c) **7** (d) **8** (b) **9** (d) **10** (c)

11 (d)

12 Atomic mass of element X = Contribution of ^{4}X in the atomic mass + Contribution of ^{5}X in the atomic mass

$= 4.035 + 4.088 = 8.123$ u

13 Contribution of ^{12}X in the atomic mass

= Atomic mass of element X – Contribution of ^{14}X in the atomic mass

$= 12.3 - 1.05 = 11.25$ u

14 Nuclear binding energy = Binding energy per nucleon × Number of nucleons

$= 6.974 \times 14 = 97.636$ MeV

$$\text{Mass defect} = \frac{\text{Nuclear binding energy}}{931} = \frac{97.636}{931} = 0.105 \text{ u}$$

$\because$ Number of protons = Atomic number = 7 protons

$\therefore$ Number of neutrons = Mass number – Atomic number = 14 – 7 = 7 neutrons

Theoretical mass = (No. of protons × Proton mass) + (No. of neutrons × Neutron mass) = (7 × 1.00728) + (7 × 1.0087) = 14.11 u

Actual mass = Theoretical mass – Mass defect = 14.11 – 0.105 = 14.005 u

---

15 Number of neutrons = $\frac{\text{Mass of neutrons}}{\text{Mass of neutron}} = \frac{3.02598}{1.00866} = 3$ neutrons

Number of nucleons = Number of protons + Number of neutrons

= 3 + 3 = 6 nucleons

Nuclear binding energy = 5.1205 × 6 = 30.723 MeV

Mass defect = $\frac{30.723}{931} = 0.033$ u

Theoretical mass = (3 × 1.00728) + 3.02598 = 6.04782 u

$\therefore$ Actual mass = 6.04782 – 0.033 = 6.01482 u

---

16 Nuclear binding energy = 34.1411 × 14 = 477.9754 MeV

Mass defect = $\frac{477.9754}{931} = 0.5134$ u

Theoretical mass = Actual mass + Mass defect

= 13.6 + 0.5134 = 14.1134 u

Assuming that no. of protons = Z $\quad\therefore$ No. of neutrons = 14 – Z

Theoretical mass = (No. of protons × Proton mass) + (No. of neutrons × Neutron mass)

$14.1134 = (Z \times 1.0073) + \big((14 - Z) \times 1.0087\big)$

$14.1134 = 1.0073\,Z + 14.1218 - 1.0087\,Z$

$-8.4 \times 10^{-3} = -1.4 \times 10^{-3}\,Z$

$\therefore Z = 6$

$\because$ Atomic number = No. of protons

$\therefore$ Atomic number = 6

17 $^{244}_{94}C$ / Because number of nucleons in it is higher than the stability level.

18 Above the belt of stability / It can reach the stability state by emitting alpha particles.

19 Because $\frac{N}{Z}$ ratio in element A $(\frac{20}{20})$ equals 1 , while in element B $(\frac{30}{10})$ equals 3 which is high.

20 Decayed mass $= 24 \times \frac{93.75}{100} = 22.5$ g

$\therefore$ Remained mass $= 24 - 22.5 = 1.5$ g

$$24 \xrightarrow[(1)]{t_{\frac{1}{2}}} 12 \xrightarrow[(2)]{t_{\frac{1}{2}}} 6 \xrightarrow[(3)]{t_{\frac{1}{2}}} 3 \xrightarrow[(4)]{t_{\frac{1}{2}}} 1.5$$

$\because$ D = 4

$\therefore$ $t = t_{\frac{1}{2}} \times D = 14 \times 4 = 56$ years

21 $D = \frac{t}{t_{\frac{1}{2}}} = \frac{3}{0.5} = 6$

$$0.25 \text{ g} \xrightarrow[(6)]{t_{\frac{1}{2}}} 0.5 \text{ g} \xrightarrow[(5)]{t_{\frac{1}{2}}} 1 \text{ g} \xrightarrow[(4)]{t_{\frac{1}{2}}} 2 \text{ g} \xrightarrow[(3)]{t_{\frac{1}{2}}} 4 \text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} 8 \text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} 16 \text{ g}$$

$\therefore$ The original mass = 16 g

Answers of the exam model about Unit 5

1 (a)	**2** (c)	**3** (d)	**4** (d)	**5** (c)
6 (d)	**7** (a)	**8** (b)	**9** (d)	**10** (b)

11 **(1)** $^{10}_{5}B + ^{1}_{0}n \longrightarrow {}^{7}_{3}Li + {}^{4}_{2}He$

(2) Stable / Because $\frac{N}{Z} = \frac{4}{3} = 1.3$ (less than 1.53).

12 Contribution of magnesium –24 in the atomic mass = $23.985 \times \frac{78.99}{100} = 18.946$ u

Contribution of magnesium –25 in the atomic mass = $24.986 \times \frac{10}{100} = 2.499$ u

Contribution of magnesium –26 in the atomic mass = $25.983 \times \frac{11.01}{100} = 2.861$ u

Atomic mass of magnesium element Mg = 18.946 + 2.499 + 2.861 = 24.306 u

13 $D = \frac{t}{t_{\frac{1}{2}}} = \frac{2.5}{0.5} = 5$

$0.0625\ g \xrightarrow[(5)]{t_{\frac{1}{2}}} 0.125\ g \xrightarrow[(4)]{t_{\frac{1}{2}}} 0.25\ g \xrightarrow[(3)]{t_{\frac{1}{2}}} 0.5\ g \xrightarrow[(2)]{t_{\frac{1}{2}}} 1\ g \xrightarrow[(1)]{t_{\frac{1}{2}}} 2\ g$

$\therefore$ The original mass = 2 g

14 $m\ (kg) = \frac{0.003}{1000} = 3 \times 10^{-6}$ kg

$E = m \times c^2 = 3 \times 10^{-6} \times (3 \times 10^8)^2 = 2.7 \times 10^{11}$ J

15

	(1) Neon –24	(2) Chlorine –32
Location	At the left side of the belt of stability	At the right side of the belt of stability
Explanation	Because number of neutrons in it is higher than the stability level "$\frac{N}{Z}$ ratio is high"	Because number of protons in it is higher than the stability level "$\frac{N}{Z}$ ratio is small"
Type of emitted radiation	Beta particle β^-	Positron β^+

16 $^{109}_{46}Pd \longrightarrow {}^{109}_{47}Ag + {}^{0}_{-1}e$

17 * **The first equation :** $^{14}_{7}N + {}^{4}_{2}He \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H$

* **The second equation :** $^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n$

Answers of Exam model 1

1 (b)	2 (c)	3 (c)	4 (c)	5 (d)
6 (d)	7 (c)	8 (a)	9 (a)	10 (d)

11 $2CH_3OH \longrightarrow \Delta H$

$2 \times 32 = 64$ g ? kJ

0.934 g −20.6 kJ

$\Delta H = \frac{-20.6 \times 64}{0.934} = -1411.56$ kJ

12 Because γ−rays are electromagnetic waves with no mass or charge.

13 4000 decay/min $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 2000 decay/min $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1000 decay/min $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 500 decay/min

$\because D = 3 \quad \therefore t_{\frac{1}{2}} = \frac{t}{D} = \frac{72}{3} = 24$ min

14 $q_p = mc\Delta T = 48.7 \times 4.18 \times (62 - 22.8) = 7979.79$ J $= 7.98$ kJ

15 Energy absorbed during breaking reactants bonds =

$[2 \times 2(S = O) + (O = O)] = [(4 \times 534) + 498] = +2634$ kJ

Energy released during the formation of products bonds $= [2 \times 3(S = O)]$

$\because \Delta H =$ Energy absorbed during breaking reactants bonds "with positive sign" + Energy released during the formation of products bonds "with negative sign"

$\therefore -196 = (+2634) + [-6\,(S = O)]$

$6\,(S = O) = 2634 + 196 = 2830$ kJ

Average bond energy of (S = O) in SO_3 molecule $= \frac{2830}{6} = 471.67$ kJ/mol

So, the average bond energy of (S = O) in SO_3 molecule differs from that in SO_2 molecule.

(16) $^{214}_{85}A$, $^{210}_{84}B$

(17) (1) Beta particle. (2) Alpha particle.

Answers of Exam model 2

(1) (a)	(2) (b)	(3) (c)	(4) (a)	(5) (d)
(6) (d)	(7) (b)	(8) (c)	(9) (d)	(10) (b)

(11) $^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n$

X : Deuterium nucleus **Y** : Tritium nucleus **Z** : Helium nucleus

(12) **By multiplying equation ① × 2 :**

$N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)}$

$\Delta H_3 = \Delta H_1 \times 2 = (30 \times 2) = +60$ kJ ③

By subtracting equation ② from equation ③ :

$\cancel{N_{2(g)}} + \cancel{2O_{2(g)}} - \cancel{N_{2(g)}} - \cancel{2O_{2(g)}} \longrightarrow 2NO_{2(g)} - N_2O_{4(g)}$

$\Delta H = \Delta H_3 - \Delta H_2 = (60 - 10) = +50$ kJ

By transferring N_2O_4 to the left side of the equation with an opposite sign :

$N_2O_{4(g)} \longrightarrow 2NO_{2(g)}$ $\Delta H = +50$ kJ

(13) Cobalt–60 isotope is used outside the body / because gamma rays emitted from it have an ability to penetrate the body tissues to reach the tumor,

While radium–226 isotope is implanted in the tumor inside the body / because alpha particles emitted from it can't penetrate the body tissues.

(14) The copper piece / Because its specific heat is less than that of iron.

15 ΔH_c° = Sum of heat of formation of products

– Sum of heat of formation of reactants

$$\Delta H_c^\circ = [\Delta H^\circ_{f(CO_2)} + 2\Delta H^\circ_{f(H_2O)}] - [\Delta H^\circ_{f(CH_3OH)} + \Delta H^\circ_{f(O_2)}]$$

$$= [(-393.51) + (2 \times -285.5)] - [(-238) + 0] = -726.51 \text{ kJ/mol}$$

16 **(1)** Nuclear fission reaction.

(2) Because neutrons produced from it act as new projectiles for similar fission reactions and the reaction continues spontaneously.

17 No. of moles of glucose $= \dfrac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$

$$= \frac{1.3}{180} = 7.2 \times 10^{-3} \text{ mol}$$

$q_p = -(\Delta H_c^\circ \times n)$

$q_{p(Glucose)} = -(-2816 \times 7.2 \times 10^{-3}) = +20.2752 \text{ kJ} = +20275.2 \text{ J}$

$\because$ Quantity of heat produced from combustion of 1.3 g of glucose

= Quantity of heat required to raise the temperature of water by 24.3°C

$\therefore q_{p(Water)} = mc\Delta T$

$\therefore m = \dfrac{q_p}{c\Delta T} = \dfrac{+20275.2}{4.18 \times 24.3} = 199.61 \text{ g}$

Answers of Exam model 3

1 (a)	2 (a)	3 (c)	4 (b)	5 (d)
6 (d)	7 (c)	8 (b)	9 (c)	10 (c)

11 Separation of molecules or ions of the solute from each other.

12 The solution will be endothermic.

13

C_4H_{10}	⟶	q_p
1 g		+49.7 kJ
100 g		? kJ

* The quantity of released heat from burning 100 g of butane :

$q_{p(Butane)} = 100 \times 49.7 = 4970$ kJ

C_8H_{18}	⟶	q_p
1 g		+47.9 kJ
200 g		? kJ

* The quantity of released heat from burning 200 g of octane :

$q_{p(Octane)} = 200 \times 47.9 = 9580$ kJ

∴ The total released heat :

$q_{p(Total)} = q_{p(Butane)} + q_{p(Octane)} = 4970 + 9580 = 14550$ kJ

14 At the left side of the belt of stability.

15

	β^+	β^-
Similarity	Each one is emitted from an unstable nucleus of an element atom to reach the stable state	
Difference	The charge type is	
	a positive electron of nucleus	a negative electron of nucleus

16 **(1)** To preserve it from spoiling and prolong its storage time.

(2) It indicates that the container contains radioactive elements and must be handled with caution.

17 **(1)** $^2_1H + {}^3_1H \longrightarrow {}^4_2He + {}^1_0n$

(2) 1– Mass defect

= The mass of the fused nuclei – The mass of the produced nucleus

= 5.031 – 5.011 = 0.02 u

E (MeV) = 0.02 × 931 = 18.62 MeV

2– E (J) = $18.62 \times 1.6 \times 10^{-13} = 2.9792 \times 10^{-12}$ J

Answers of Exam model 4

1 (c)	2 (a)	3 (a)	4 (a)	5 (c)
6 (b)	7 (b)	8 (a)	9 (c)	10 (b)

11 $^{A-4}_{Z-2}Y$

12 Because the conversion of ice into liquid water requires absorbing an amount of heat energy to break the hydrogen bonds between the ice molecules.

13 $\because c = 4.18 \frac{J}{g.°C} = \frac{4.18}{10^{-3}} \frac{J}{kg.°C}$

$\therefore$ c (J/kg.°C) = 4.18 × 1000 = 4180 J/kg.°C

14 * **For element (X) :**

$\because \frac{N}{Z} = 1$, Z = 5 $\therefore$ N = 5

The number of nucleons in the nucleus of each of (X) or (Y)

= 5 + 5 = 10 nucleons

* **For element (Y) :**

$\because \frac{N}{Z} = \frac{1.5}{1} \xrightarrow{\times 4} = \frac{6}{4}$

$\therefore$ N = 6 , Z = 4

$\therefore$ The chemical symbol of the nucleus of the stable atom of the element Y is $^{10}_{4}Y$

(15)

H_2O	⟶	q_p
18 g/mol		+54 kJ/mol
100 g		? kJ

The quantity of heat required to convert 100 g of water to water vapor at 100°C :

$$q_{p_{(1)}} = \frac{100 \times 54}{18} = 300 \text{ kJ}$$

The quantity of heat required to raise the temperature of 100 g of water from 20°C to 100°C :

$\because q_{p_{(2)}} = m c \Delta T = 100 \times 4.18 \times (100 - 20) = 33440 \text{ J} = 33.44 \text{ kJ}$

$\therefore$ The total energy required to convert 100 g of water to water vapor

$q_{p(Total)} = q_{p_{(1)}} + q_{p_{(2)}} = 300 + 33.44 = 333.44 \text{ kJ}$

---

(16) **(1)** Alpha radiations are not used as it can't penetrate the paper (weak), while gamma rays have very high penetration ability. So, they totally penetrate the paper.

(2) $^{90}_{39}Y + ^{0}_{-1}e$

---

(17) Mass of reactants = 234.9933 + 1.0087 = 236.002 u

Mass of products = 91.9064 + 140.8836 + (3 × 1.0087) = 235.8161 u

Mass defect = Mass of reactants – Mass of products

= 236.002 – 235.8161 = 0.1859 u

The quantity of heat released = Mass defect × 931

= 0.1859 × 931 = 173.0729 MeV

Answers of Exam model 5

1 (a)	2 (b)	3 (c)	4 (a)	5 (b)
6 (a)	7 (a)	8 (a)	9 (d)	10 (c)

(11) $^{99}_{43}Tc \longrightarrow {}^{98}_{44}Ru + {}^{0}_{-1}e + {}^{1}_{0}n$

(12) **(1)** (A/Solvent), (B/Solute).

(2) With negative sign/ Because it is an exothermic process, due to the releasing of energy during the combination of solvent molecules with solute molecules.

(13) $D = \frac{t}{t_{\frac{1}{2}}} = \frac{1.5}{0.5} = 3$

6000 decay/s $\xrightarrow[(1)]{t_{\frac{1}{2}}}$ 3000 decay/s $\xrightarrow[(2)]{t_{\frac{1}{2}}}$ 1500 decay/s $\xrightarrow[(3)]{t_{\frac{1}{2}}}$ 750 decay/s

$\therefore$ The counter reading is 750 decay/second

(14) $AlCl_3 < Al(OH)_3 < Al_2(SO_4)_3$

(15) **(1)** $^{90}_{38}Sr + {}^{144}_{54}Xe + 2\,{}^{1}_{0}n$

(2) Number of neutrons increases.

(16) Number of neutrons = Mass number – Atomic number

$= 8 - 4 = 4$ neutrons

Theoretical mass =

(No. of protons × Proton mass) + (No. of neutrons × Neutron mass)

$= (4 \times 1.673 \times 10^{-27}) + (4 \times 1.675 \times 10^{-27})$

$= 1.3392 \times 10^{-26}$ kg

Mass defect = Theoretical mass – Actual mass

$= (1.3392 \times 10^{-26}) - (1.329 \times 10^{-26}) = 1.02 \times 10^{-28}$ kg

$BE\ (J) = mc^2 = 1.02 \times 10^{-28} \times (3 \times 10^8)^2 = 9.18 \times 10^{-12}$ J

$\text{Binding energy per nucleon} = \frac{\text{Binding energy}}{\text{Mass number}}$

$= \frac{9.18 \times 10^{-12}}{8} = 1.148 \times 10^{-12}$ J

---

(17) $q_{p(Copper)} = mc\Delta T = 50 \times 0.385 \times 10 = 192.5$ J

$q_{p(Water)} = q_{p(Copper)} = 192.5$ J

$\therefore \Delta T_{(Water)} = \frac{q_p}{mc} = \frac{192.5}{10 \times 4.18} = 4.6\,°C$

Answers of Exam model 6

(1) (c)	(2) (b)	(3) (c)	(4) (d)	(5) (b)
(6) (b)	(7) (b)	(8) (d)	(9) (b)	(10) (b)

---

(11) $c\ (J/g.°C) = \frac{1970}{1000} = 1.97$ J/g.°C

$q_p = mc\Delta T = 1500 \times 1.97 \times (180 - 20) = 472800$ J $= 472.8$ kJ

---

(12) The quantity of heat absorbed at the dissolution of 1 mol of silver iodide in an amount of solvent to form 1 L of solution equals 84.4 kJ

---

(13) The contribution of boron – 10 in the atomic mass $= 10 \times \frac{20}{100} = 2$ u

The contribution of boron – 11 in the atomic mass $= 11 \times \frac{80}{100} = 8.8$ u

$\therefore$ The atomic mass of boron element $= 2 + 8.8 = 10.8$ u

---

(14)
- **(X)** : Alpha radiation / Because it has positive charge, so it is slightly deviated towards the positive pole.
- **(Y)** : Gamma ray / Because it is not affected by the electric field.

(15) $C_4H_{10(g)} + \frac{13}{2} O_{2(g)} \longrightarrow 4CO_{2(g)} + 5H_2O_{(\ell)}$ $\Delta H^\circ_c = -2877$ kJ/mol

$\because \Delta H^\circ_{f(CO_2)} = \Delta H^\circ_{c(C)} = -393.5$ kJ/mol

$\because \Delta H^\circ_{f(H_2O)} = \Delta H^\circ_{c(H_2)} = -285.85$ kJ/mol

$\therefore \Delta H^\circ_c = [4\Delta H^\circ_{f(CO_2)} + 5\Delta H^\circ_{f(H_2O)}] - [\Delta H^\circ_{f(C_4H_{10})} + \frac{13}{2} \Delta H^\circ_{f(O_2)}]$

$-2877 = [(4 \times -393.5) + (5 \times -285.85)] - [\Delta H^\circ_{f(C_4H_{10})} + (\frac{13}{2} \times 0)]$

$-2877 = -3003.25 - \Delta H^\circ_{f(C_4H_{10})}$

$\therefore \Delta H^\circ_{f(C_4H_{10})} = -3003.25 + 2877 = -126.25$ kJ/mol

---

(16) **By multiplying equation (2) × 2 :**

$2O_2 \longrightarrow 4O$ $\Delta H_5 = \Delta H_2 \times 2 = (+498 \times 2) = +996$ kJ (5)

By multiplying equation (3) × 2, then reversing the reaction direction :

$4H + 2O \longrightarrow 2H_2O$ $\Delta H_6 = 2 \times -927 = -1854$ kJ (6)

By reversing the reaction direction of equation (4) :

$C + 2O \longrightarrow CO_2$ $\Delta H_7 = -1608$ kJ/mol (7)

By adding equations (1), (5), (6) and (7) :

$CH_4 + 2O_2 + \cancel{4H} + \cancel{2O} + \cancel{C} + \cancel{2O} \longrightarrow \cancel{C} + \cancel{4H} + \cancel{4O} + 2H_2O + CO_2$

$\Delta H = (+1663 + 996 - 1854 - 1608)$ kJ

$CH_4 + 2O_2 \longrightarrow 2H_2O + CO_2$ $\Delta H = -803$ kJ/mol

---

(17) The quantity of heat released from the combustion of 2.97 g of olive oil :

$q_{p(\text{Olive oil})} = -(\Delta H \times m)$

$= -(-41 \times 2.97) = 121.77$ kJ

The quantity of heat required to heat 500 g of water

= The quantity of released heat – The quantity of lost heat

$q_{p(Water)} = q_{p(Olive\ oil)} - q_{p(Lost)} = 121.77 - 28 = 93.77\ kJ = 93770\ J$

$\because\ q_{p(Water)} = m\,c\,\Delta T$

$$\Delta T = \frac{q_p}{m\,c} = \frac{93770}{500 \times 4.18} = 44.87^{\circ}C$$

$\therefore\ T_2 = \Delta T + T_1 = 44.87 + 21 = 65.87^{\circ}C$

Answers of Exam model 7

(1) c	(2) b	(3) a	(4) d	(5) c
(6) b	(7) d	(8) b	(9) a	(10) c

(11) $NO_{(g)} < N_2O_{(g)} < NO_{2(g)} < N_2O_{4(g)}$

(12) By adding the two equations :

$$NaCl_{(s)} + \cancel{Na^+_{(g)} + Cl^-_{(g)}} \xrightarrow{H_2O} \cancel{Na^+_{(g)} + Cl^-_{(g)}} + Na^+_{(aq)} + Cl^-_{(aq)}$$

$\Delta H = [788 + (-784)]\ kJ/mol$

$$\therefore\ NaCl_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)} \qquad \Delta H = +4\ kJ/mol$$

(13) Because the electrical repulsive forces between the protons in the nucleus have no equivalent (offset) attractive forces between neutrons and protons, as it has no neutrons.

(14) * **Natural transmutation reactions :**

In which emission of alpha, beta or gamma radiation from the nucleus of a radioactive element occurs.

* **Elemental transmutation reactions :**
In which the nucleus of an element (called target) is bombarded with a projectile which has adequate kinetic energy (called bomb), so it is transformed to a nucleus of a new element.

15 (1) $^{1}_{1}H$ (2) $^{1}_{0}n$ (3) $^{0}_{-1}e$ (4) $^{4}_{2}He$

16 Number of neutrons = Mass number – Atomic number
= 127 – 53 = 74 neutrons

Theoretical mass
= (No. of protons × Proton mass) + (No. of neutrons × Neutron mass)
= (53 × 1.00728) + (74 × 1.00866) = 128.02668 u

Mass defect = Theoretical mass – Actual mass
= 128.02668 – 126.9004 = 1.12628 u

BE = Mass defect × 931
= 1.12628 × 931 = 1048.56668 MeV

$$\text{Binding energy per nucleon} = \frac{\text{Binding energy}}{\text{Number of nucleons}}$$

$$= \frac{1048.56668}{127} = 8.25643055 \text{ MeV}$$

17

$2SO_{2(g)} \longrightarrow q_p$

(2 × 64 = 128 g) +198.2 kJ

87.9 g ? kJ

$$q_p = \frac{87.9 \times 198.2}{128} = +136.108 \text{ kJ}$$

Answers of Exam model 8

1 (a)	2 (d)	3 (c)	4 (b)	5 (d)
6 (b)	7 (a)	8 (a)	9 (c)	10 (d)

11 The specific heat of the liquified ammonia is higher than that of water.

(12) $\because q_p = mc\Delta T$

$\therefore m = \frac{q_p}{c\Delta T} = \frac{218400}{4.18 \times (100 - 35)} = 803.8$ g

(13) $m = 235 \times 1.7 \times 10^{-10} = 3.995 \times 10^{-8}$ kg

(14) Radiowaves / Affects fertility.

(15) (1) * **The similarity :** They have the same atomic number.

* **The difference :** They have different mass numbers due to the difference in number of neutrons.

(2) The contribution of (^{151}Eu) in the atomic mass = $151 \times \frac{47.77}{100}$

= 72.1327 u

The contribution of (^{153}Eu) in the atomic mass = $153 \times \frac{52.23}{100}$

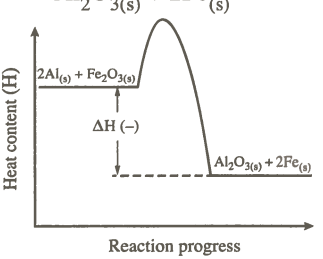
= 79.9119 u

$\therefore$ The atomic mass of europium element (Eu) = 72.1327 + 79.9119

= 152.0446 u

(16) (1) $2Al_{(s)} + Fe_2O_{3(s)} \longrightarrow Al_2O_{3(s)} + 2Fe_{(s)}$

(2)



(17) The difference in the value of ΔH_c for each carbon atom

= (The change in combustion enthalpy of 1– pentanol)

– (The change in combustion enthalpy of 1–butanol)

= (–3331) – (–2678) = –653 kJ/mol

$\because$ Ethanol contains 2 carbon atoms.

$\therefore$ The combustion enthalpy change of ethanol =

$2 \times -653 = -1306$ kJ/mol

Answers of Exam model 9

1 (b)	2 (c)	3 (d)	4 (d)	5 (b)
6 (a)	7 (a)	8 (d)	9 (c)	10 (c)

(11) Number of moles (n) = $\frac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$

$= \frac{2.8}{81} = 0.0346$ mol

$q_p = -(\Delta H \times n) = -(-216 \times 0.0346) = +7.4736$ kJ

(12) $m\ (kg) = m\ (u) \times 1.66 \times 10^{-27}$

$= 64.9278 \times 1.66 \times 10^{-27} = 1.0778 \times 10^{-25}$ kg

(13) $\Delta H = [\Delta H^\circ_{f(CH_3OH)}] - [\Delta H^\circ_{f(CH_4)} + \frac{1}{2}\Delta H^\circ_{f(O_2)}]$

$= (-239) - (-75 + 0) = -164$ kJ/mol

(14) $Q_n = u + d + d = \frac{2}{3} + (-\frac{1}{3}) + (-\frac{1}{3}) = 0$

(15) The substance is highly soluble in water/ Because the hydration energy (ΔH_3) is greater than the sum of the absorbed heat during separation of the molecules of solvent from each other and those of solute from each other ($\Delta H_1 + \Delta H_2$).

(16) Binding energy (BE) in ^4_2He

= Binding energy per nucleon $\times$ Number of nucleons $= 7.2 \times 4 = 28.8$ MeV

The energy produced from nuclear fusion

= Binding energy in ^1_1H + Binding energy in $^4_2He = 0 + 28.8 = 28.8$ MeV

The energy produced from the nuclear fusion (J) = $28.8 \times 1.6 \times 10^{-13}$

$= 4.608 \times 10^{-12}$ J

(17) By dividing equation ③ ÷2

$\frac{1}{2}Cl_{2(g)} \longrightarrow Cl_{(g)}$ $\qquad \Delta H_6 = \frac{242}{2} = +121$ kJ/mol ⑥

By reversing the equation ⑤ :

$NaCl_{(s)} \longrightarrow Na_{(s)} + \frac{1}{2}Cl_{2(g)}$ $\qquad \Delta H_7 = +411$ kJ/mol ⑦

By adding the equations ①, ②, ⑥, ④ and ⑦ :

$Na_{(s)} + Na_{(g)} + \frac{1}{2}Cl_{2(g)} + Cl_{(g)} + e^- + NaCl_{(s)} \longrightarrow$

$Na_{(g)} + Na^+_{(g)} + e^- + Cl_{(g)} + Cl^-_{(g)} + Na_{(s)} + \frac{1}{2}Cl_{2(g)}$

$\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_6 + \Delta H_4 + \Delta H_7$

$= [+109 + 494 + 121 + (-364) + 411]$ kJ

$NaCl_{(s)} \longrightarrow Na^+_{(g)} + Cl^-_{(g)}$ $\qquad \Delta H = +771$ kJ/mol

Answers of Exam model 10

(1) (b)	(2) (a)	(3) (d)	(4) (d)	(5) (c)
(6) (d)	(7) (d)	(8) (b)	(9) (b)	(10) (b)

(11) $D = \frac{t}{t_{\frac{1}{2}}} = \frac{312}{78} = 4$

$6\text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} 3\text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} 1.5\text{ g} \xrightarrow[(3)]{t_{\frac{1}{2}}} 0.75\text{ g} \xrightarrow[(4)]{t_{\frac{1}{2}}} 0.375\text{ g}$

∴ The remaining mass = 0.375 g

(12) $m\text{ (kg)} = \frac{0.5}{1000} = 5 \times 10^{-4}$ kg

$E = m \times c^2 = 5 \times 10^{-4} \times (3 \times 10^8)^2 = 4.5 \times 10^{13}$ J

(13) By multiplying equation ① × $\frac{1}{2}$, then reversing the reaction direction :

$NH_{3(g)} \longrightarrow \frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)}$ $\quad \Delta H_4 = +91.8 \times \frac{1}{2} = +45.9$ kJ ④

By reversing reaction ② direction :

$CH_{4(g)} \longrightarrow C_{(s)} + 2H_{2(g)}$ $\quad \Delta H_5 = +74.9$ kJ ⑤

By multiplying equation ③ × $\frac{1}{2}$:

$\frac{1}{2}H_{2(g)} + C_{(s)} + \frac{1}{2}N_{2(g)} \longrightarrow HCN_{(g)}$ $\quad \Delta H_6 = +270.3 \times \frac{1}{2} = +135.15$ kJ ⑥

By adding the equations ④, ⑤ and ⑥ :

$$NH_{3(g)} + CH_{4(g)} + \frac{1}{2}H_{2(g)} + \cancel{C_{(s)}} + \cancel{\frac{1}{2}N_{2(g)}} \longrightarrow$$

$$\cancel{\frac{1}{2}N_{2(g)}} + \frac{3}{2}H_{2(g)} + \cancel{C_{(s)}} + 2H_{2(g)} + HCN_{(g)}$$

$\Delta H = \Delta H_4 + \Delta H_5 + \Delta H_6 = (+45.9 + 74.9 + 135.15)$ kJ

By transferring $\frac{1}{2}H_{2(g)}$ to the right side with an opposite sign :

$\therefore NH_{3(g)} + CH_{4(g)} \longrightarrow 3H_{2(g)} + HCN_{(g)}$ $\quad \Delta H = +255.95$ kJ

---

(14) $235 + 1 = A + 97 + 2$

$\therefore A = 137$

$92 + 0 = Z + 40 + 0$

$\therefore Z = 52$

Number of neutrons = A – Z = 137 – 52 = 85 neutrons

Number of electrons = Number of protons = 52 electrons

15 ∵ Specific heat is estimated in (J/mol.°C)

∴ n is used in ($q_p = mc\Delta T$) instead of m

∴ $q_p = nc\Delta T$

∵ No. of moles (n) = $\frac{\text{Mass of the substance}}{\text{Molar mass of the substance}} = \frac{500}{18} = 27.78$ mol

∴ $q_p = nc\Delta T = 27.78 \times 75.4 \times (0 - 20)$

$= -41892.24$ J

$= -41.8922$ kJ

∵ Each piece of ice contains 1 mol of water.

No. of ice pieces	q_p
1	– 6.02 kJ
?	– 41.89224 kJ

∴ No. of ice pieces = $\frac{-41.89224 \times 1}{-6.02} \simeq 7$ pieces

---

16 The energy absorbed during breaking reactants bonds =

[(C – C) + 4(C – H) + 2(C – Cl)] =

[347 + (4 × 413) + (2 × 346)] = +2691 kJ

The energy released during the formation of products bonds =

[(C = C) + 3(C – H) + (C – Cl) + (H – Cl)] =

[(–612) + (3 × –413) + (–346) + (–432)] = –2629 kJ

ΔH = Energy absorbed during breaking the reactants bonds

+ Energy released during the formation of products bonds

ΔH = 2691 + (–2629) = +62 kJ/mol

---

17 (1) $\frac{N}{Z} = \frac{121 - 51}{51} = 1.37$

∴ The ratio $\frac{N}{Z} = 1.37$ (is less than 1.53)

∴ The isotope $^{121}_{51}Sb$ is stable.

(2) $^{117}_{51}Sb \longrightarrow {}^{117}_{52}Te + {}^{0}_{-1}e$